AUS DEM LEHRSTUHL FÜR KIEFERORTHOPÄDIE

PROF. DR. DR. PETER PROFF

DER FAKULTÄT FÜR MEDIZIN

DER UNIVERSITÄT REGENSBURG

“MANDIBULAR AND CONDYLAR MOVEMENTS IN CHILDREN AND ADULTS –

a trial on kinematic parameters and their association with individual characteristics”

Inaugural - Dissertation

zur Erlangung des Doktorgrades

der Zahnmedizin

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vorgelegt von

Zoi Kardari

aus Griechenland

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To my family

for their support all these years

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1. Introduction

The stomatognathic system consists of the teeth, the periodontal tissues, the maxilla and the mandible, the bilateral temporomandibular joint (TMJ), soft tissues, the tongue, orofacial muscles, nerves and vessels. The TMJ is a complex and highly mobile joint, as the two condyles of the mandible must function simultaneously in great harmony [Okeson 2007, p.19]. Due to their complexity, TMJ problems are often difficult to diagnose accurately. The function of the stomatognathic system is of great interest to dentists and especially to orthodontists. Temporomandibular joint dysfunctions are an important reason for patients to visit the dentist or the orthodontist. The treatment requirements are also controversial. In patients with dysfunction of the temporomandibular joint, it is necessary to accurately record the movements of the mandible before any restorative or orthodontic treatment. According to the National Institute of Dental and Craniofacial Research (NIDCR) the prevalence of temporomandibular joint and muscle disorder (TMJD) ranges between 5% and 12%. The prevalence of TMJ disorders is higher among younger individuals and women are at least twice as often affected as men [www.nidcr.nih.gov 04.10.2010]. In a study by Johansson et al. 2002 in a Swedish population, 8.2% of the males and 11.2% of the females had difficulties in jaw opening. The results are similar to those from an adult Chinese population in Hong Kong [Pow et al., 2002]. The respective results were 7.5% for the men and 8.9% for the women. Therefore, it is important to understand the normal function of the temporomandibular joint. Many efforts have been made to record the movements of the mandible instrumentally, in order to understand the biomechanics of the temporomandibular joint and, thus, to be able to diagnose TMJ dysfunctions and to plan treatment. Many studies have been published about the analysis of mandibular function. Some of the studies are based on clinical examination. As dentists' understanding of the role of the TMJ in normal function of the stomatognathic system increased, techniques have been developed that would enable a functional instrumental analysis of the TMJ and the mandible. Various methods have been used to study the range of mandibular movements. The most common of them are graphic and pantographic recordings, rapid serial cephalometry, tomography and cinefluorography [Kydd 1958]. Gysi 1910 described a graphic method to trace the movement of the mandible. One of the first attempts was made by McCollum in 1924, when he discovered the first positive method of locating the hinge Axis. He founded the Gnathological Society of California in 1926. A device was designed to record mandibular movements in three planes, using tracing plates placed extraoral. In 1934, a more advanced device had been developed, i.e. the McCollum gnathograph, which not only could record the mandibular movements in three planes but, also reproduce them accurately [http://www.gnathologyusa.org/History.html 22.11.2010]. After a few years Stuart introduced a pantograph and articulator and received a patent in 1955 [Mc Collum 1955, Starcke 2002]. Then, the Denar pantograph and articulator followed (Denar Corp., Anaheim, Calif.) [Denar 1966, Donaldson 1986]. Since then a lot of progress has been made in this field. The goal was to construct a more accurate, less complex, lighter, and easier-to-use device. These first devices were relative large and heavy. They consisted of an extra-oral face-bow, tracing plates and pins that should be fastened to the patients in order to record the mandibular movements. They should be light enough not to affect the movements. Later, the mechanical registration systems were replaced by computer-supported ones. At that time, it was important to find out if the two systems were compatible and if they were both reliable. In a study of Kucukkeles et al. 2005, the mechanical and computerized axiographs were compared. The results showed no significant differences between the recordings of the two systems. Nevertheless, according to this study minor differences could result due to hand measuring errors for the tracings generated by the mechanical axiograph. Therefore, the computer supported systems gained ground, as they also were easier to use, more friendly to the patients as the pins were replaced by electronic sensors and required less time for examination. Hence, researchers were enabled to record in great accuracy the movements of the jaw and the condyles in 3 dimensions, through electronic jaw tracking devices, such as the JMA System of Analysis (Jaw Motion Analyzer, Zebris

Medical GmbH, Allgäu, Germany) which is an ultrasound based system for registration [Hugger 2001, Baqaien 2006/ 2008, Reicheneder et al., 2008/ 2009], the Cadiax Compact (Gamma-A, Klosterneuburg) [Slavicek 1988, Celar 2002] which is an electro-mechanic based system for registration, or the 3Space Fastrak System (Polhemus, Colchester, VT) the function of which is based on patented low-frequency magnetic transducing technology [Yoon 2006, http://www.vrlogic.com/html/ polhemus/ 3space_fastrak.html 16.10.2010].

2. *The Human temporomandibular joint*

2.1. *Anatomy*

The temporomandibular joint, or TMJ, is a complex joint which is found only in mammals between the condyle of the mandible and the mandibular fossa of the temporal bone, and regulates the mandibular movements [Smith 2001]. It is a bilateral articulation, i.e., the two condyles, must function largely synchronised to one another. A fibrocartilagious disc, the articular disc, is located between these two bones, dividing the joint cavity into two compartments. The TMJ, as a ginglymo-arthroidal joint, is able to make both rotational and translational movements [Okeson 2007, p.7]. Although the TMJ is a synovial joint, it differs from most other synovial joints, because its articular surfaces are covered by fibrocartilage instead of hyaline cartilage [Okeson 2007, p.9, Ide 1991, Purcell 2009].

The TMJ consists of the following major components: [Cohen 1960, Zola 1963, Okeson 2007, p.2-24]

- Osseous parts:
  - mandibular condyle
  - temporal bone with the articular surfaces:
    - articular fossa
    - articular eminence
    - postglenoid process
- Soft tissues:
  - articular disc
  - articular capsule - articular ligaments
- Nerves and vessels

2.1.1. Osseous parts

2.1.1.1. Mandibular condyle

The condyle is the osseous part of the mandible that articulates with the temporal bone in the mandibular fossa. The condylar length is the largest dimension of the condyle in the anteroposterior plane. The mediolateral length and the anteroposterior width of the condyles vary between 18-23 mm and 8-10 mm respectively [Okeson 2007, p. 5-6]. The condyle appears to have a great variability in shape and size. According to Karlo et al. 2010 the condylar shape and size as determined on sagittal images are significantly associated with the age. The size of the condyles increases with age, and the shape of the condyle changes from round to oval. In this study the condyles were categorized into three types: type I showed a round shape, which is most frequently seen in children aged 0–5 years; type II showed an anterior beak. This anterior beak is more common in type III where a flattening of the condyle’s anterior surface is also observed in children aged 10 years and older. Also, according to Katsavrias et al. 2006, an oval condylar shape is most common in Class II,2 subjects. Meng at al. 2008 found that the shape of the condyle in children is almost round, and smaller compared to the fossa. In the frontal plane, condylar shape was found to be slightly rounded, flat or gabled whereas in the sagittal plane, the condylar shape was either convex or locally concave or wedged. In the horizontal plane, the condyle can have an elliptical, cylindrical or irregular shape. The elliptical shape is found to be characteristic of the growing condyle which changes later during the growth period. There is an association between the shapes of the condyle and the temporal bone [Solberg 1985]. Pandis et al. 1991 categorized the condyle as convex, concave, flat and triangular in the sagittal plane. Moreover, patients with bifid condyles [Antoniades 1993/ 2004, Flavia 2006, Kaneyama 2008] and one patient with a trifid condyle [Artvinli 2003] were mentioned in the literature.

2.1.1.2. Temporal bone

2.1.1.2.1. Articular fossa

The mandibular fossa is a depression in the squamous part of the temporal bone, and is covered by fibrocartilage instead of hyaline cartilage. It is the part of the temporal bone that articulates with the condyle [Okeson 2007, p.6]. The shape of the fossa is mostly oval, but appears to have a great variability, not only among humans but also between the two TMJs of an individual. In adults, the average length of the fossa is 20 mm and the width is 25 mm [Scott 1972]. The mandibular fossa is bounded anteriorly by the articular eminence and tubercle and posteriorly by the tympanic part of the temporal bone which separates it from the external acoustic meatus [Mc Kay 1992]. Katsavrias et al. 2006 found in Class II,2 subjects that the prevalence of fossa shapes was oval in 58.3%, triangular in 18.8%, trapezoidal in 15.6% and round in 7.3%. In addition, they found that the shape of the condyles and the fossa were identical in only 52.1%. The mandibular fossa of the children was found to be flatter than in adults, which could explain why children's TMJs are more likely to dislocate [Meng et al., 2008].

2.1.1.2.2. Articular eminence

The articular eminence is the anterior boundary of the mandibular fossa. In the sagittal plane it is convex. The anatomy of the articular eminence plays a great role in the function of the TMJ. Some authors suggest that a larger articular eminence inclination may predispose to internal disorders [Hall 1985, Sato 1996/ 1999, Sulun 2001]. On the contrary, some authors do not support this opinion [Ren 1995, Kurita 2000, Kinniburgh 2000, Galante 1995]. Others authors, again, suggest that internal disorders could result from flattening of the articular eminence [Emshoff 2003, Kurita 2000]. The height of the articular eminence varies, however not significantly between the right and the left side [Katsavrias 2002, Weinberg 1978], while Lindblom 1960 found that the left one is higher. There are different classifications of the articular eminence according to its morphology. According to Kurita et al. 2000 and Hirrata et al. 2007 it may be classified into four types: box, sigmoid, flattened or deformed.

2.1.1.2.3. Postglenoid process

The postglenoid process is the posterior wall of the fossa. The postglenoid process may be completely absent. Its mean height in adults is between 5.5 and 7 mm [Katsavrias and Dibbets 2002].

2.1.2. Soft tissues

2.1.2.1. Articular disc

The articular disc is a biconcave fibrocartilaginous tissue which lies between the surfaces of the condyle inferiorly and the mandibular fossa superiorly [Rees 1954, De Brul 1980]. The disc divides the joint cavity into two compartments, the superior one and the inferior one [Ide 1991, Tanaka 2008], and follows the condyle in every movement. When the jaw opens, the condyle rotates and translates anteriorly onto the mandibular eminence, and the disc remains interposed between the condyle and the eminence, preventing the two osseous parts to come in direct contact. It acts as a cushion, absorbing stress and expediting the movement of the condyle [http://www.aaoms.org/tmj.php 22.10.2010, Ide 1991]. From the anterior view, the disc is thicker medially than laterally. In the sagittal plane the disc is divided into three regions. Its central region is thinner (1-2 mm) avascular and is called the “intermediate zone” [Okeson 2007, p.7]. The anterior and the posterior region of the disc are thicker (2-4 mm). The posterior region of the disc, which is called the bilaminar zone, is divided into two stratums and consists of fibrovascular connective tissue with laminar elastic and collagenous tissue components [Wadhwa 2008]. Through the bilaminar zone the disc is attached both to the fossa and to the condyle. The superior stratum of the bilateral zone is attached to the posterior wall of the fossa whereas the inferior stratum is attached to the posterior surface of the condyle [Shore 1976, Zenker 1954]. The articular disc is also firmly attached to the medial and lateral poles of the condyle. Anteriorly, the disc is attached to the joint capsule and anteromedially to the upper belly of the lateral pterygoid muscle [Katzberg 1989, Schmolke 1994]. The disc divides the joint into two cavities, the superior and the inferior one, and normally allows no direct contact between the articular surfaces. These two compartments of the joint are filled with synovial fluid. According to the criteria of Murakami et al. 1993 the disc can be classified according to its shape as biconcave, biplanar, biconvex, hemiconvex or folded.

2.1.2.2. Articular capsule - articular ligaments

The bones of the TMJ are held together with ligaments, which completely surround the TMJ forming the joint capsule. It attaches to the articular eminence, the articular disc and the neck of the mandibular condyle. The inner part of the capsule is comprised of the synovial membrane which secretes the synovial fluid [Ide 1991]. Each compartment of the joint is filled with synovial fluid, which serves the joint in different ways. Since the articular disc and the articular surfaces of the joint are devoid of vessels, the synovial fluid acts as a source providing metabolic elements. It has another important role: to minimize the friction during the movements, as it acts like a lubricant between the articular surfaces [Tanaka 2006, Okeson 2007, p.9]. The articular ligaments play an important role, too, because they control the limits of the mandibular movements. They comprise the temporomandibular ligament, the capsular ligaments, the collateral lingaments, the stylomandibular ligament and the sphenomandibular ligament. The temporomandibular ligament is divided into two parts, i.e. the outer oblique portion which controls maximum opening and the inner horizontal portion which controls the posterior movements of the condyle and the disc. The role of the capsular ligaments is to prevent the articular surfaces from dislocating. The collateral ligaments are responsible for disc movements and allow the disc to follow the movements of the condyle. The stylomandibular lingament controls the maximum protusion of the mandible. However, the sphenomandibular ligament does not provide a specific limitation to the movements of the mandible [Okeson 2007, p. 11-14].

2.1.2.3. Nerves and vessels

The TMJ is innervated by the masseteric nerve and the auriculotemporal nerve which are branches of the the mandibular branch, and by the third branch of the trigeminal nerve [Benner 1993 p. 50] which all provide sensory innervation. Vascularisation is provided by the superficial temporal artery, middle meningeal artery and the internal maxillary artery [Okeson 2007, p.11].

2.2. Function and movements

The TMJ is a unique articulation in the human body due to its complexity in terms of anatomical structure and function. The mechanics of the TMJ are reasonably different compared to the other joints. For instance, the two TMJs are linked to each other and, consequently, bound to cooperate during all functions of the mandible [Okeson 2007, p.19]. Thus, the function of the TMJ depends on the correct postural and functional relationship of its parts. The movements of the mandible are the result of muscular activity, controlled by the central neural system and constrained by the anatomic structures of the TMJ [Okeson 2007, p.39]. As a consequence of such complexity, little is known about the kinematics of the human TMJ. Although several investigations have been conducted, TMJ function still remains an unsolved issue in dental science. There are theories about the function of the TMJ based on complex mathematical models, such as the model of Baragar & Osborn 1984. They examined the way in which soft tissues, ligaments and bone structures can affect the threedimensional movements of the mandible during jaw opening, closing and lateral movements. In order to understand the function of the TMJ we should refer to the static relations, the dynamic relations and the functional movements of the mandible [Katsavrias 2000, p.119- 128].

The ***static relations*** of the mandible refer to the centric relation, centric occlusion, maximum intercuspation and rest jaw position. According to The Glossary of Prosthodontics Terms 2005 these terms are defined as follows:

Centric relation is the mandibular jaw position related to the maxilla in which the condyles articulate with the thinnest avascular portion of the discs, being situated in the most anterior-superior position within the articular fossa [Davies 2001]. This position shows only a bone relationship, independently of any tooth contacts and can clinically be found when the mandible is manipulated bilaterally upward and forward [Wood 1988]. The centric relation is a stable and reproducible posture of the mandible, therefore can be used as a reference position and is the treatment position for restorations in edentulous patients [Phillips 1986]. Pullinger et al. 1993 concluded that the presence of a slide from centric occlusion to maximum intercuspation of 2 mm or more indicates an increased risk for TMD.

Centric occlusion is the occlusion when the mandible is in centric relation. This may refer to one or more tooth contacts and may not coincide with the maximum intercuspation.

Maximum intercuspation is the mandibular position associated with the maximum number of possible tooth contacts. It is independent of the condylar position and may not coincide with the centric occlusion.

Rest jaw relation is this position of the mandible when the patient is seated in an upright position, the muscles are balanced and the condyles are in a neutral and unstrained position in the articular fossa. In this position a distance of about 2-3 mm exists between the upper and lower teeth, the mouth is slightly open and the lips are in contact [Garnick 1962].

The *dynamic relations* of the mandible refer to jaw opening, jaw protrusion and jaw lateralotrusions.

First of all, the movements of the human TMJ and the condyles that occur during the movements of the mandible, i.e., rotation and translation, will be described.

Rotation

Rotation occurs as the mouth opens and closes about an axis, which is defined from the two condyles. As for the TMJ, the lower joint cavity is involved in rotational movement, i.e., rotation occurs between the superior surface of the condyle and the inferior surface of the disc. The rotation is the initial movement of the jaw during mouth-opening. A rotational movement of the jaw is feasible in three planes (horizontal, vertical, sagittal) but only rotation in the horizontal plane occurs during normal function of the TMJ [Okeson 2007, p. 81- 83].

Translation

Translation (gliding or sliding movement) is defined as the movement of a rigid body in which a straight line passing through any two points always remains parallel to its initial position [The Glossary of Prosthodontics Terms 2005]. These points move with the same velocity and in the same direction. The upper joint cavity formed by the articular disc and the articular fossa-articular eminence is involved in translational movements [Okeson 2007, p. 83].

Jaw opening

During jaw opening the two different movements of the TMJ occur at the same time, viz. a rotation about an axis passing through the centers of the two condyles and a translation of the two condyles with their discs along the articular eminence [Baragar 1984, Osborn 1989]. The articular eminence and the temporomandibular ligament constrain the jaw opening. According to the findings of Osborn 1989, the condyle rotates about the lowest attachment of the TM ligament, is kept in close contact with the articular eminence and swings about the most posterior attachment of the ligament to the articular eminence during opening. In their study they found that the jaw closing movement is not constrained by the same anatomical structures as the jaw opening movement, but through the masticatory muscles the condyle moves against the anterior wall of the articular fossa. It is not clear if the condyle remains in closer contact with the articular eminence during opening or during closing. This is to say that the closing movements should not be considered as the reverse of the opening movements. The results of Yatabe et al. 1997 are in agreement with the findings of Osborn et al. 1985. They actually supported that the condyle moves in a closer contact with the articular eminence during opening than during closing.

Protrusion

During this movement the mandible moves forward in an anteroposterior plane. The two condyles move forward and downward remaining in contact with the articular eminence.

Laterotrusion

The mandible is capable of performing a lateral movement to the right and to the left. The lateral movements are even more complex than opening or protrusion because they are not symmetric movements. The muscles on the one side act in a way different from the muscles on the other side. This movement of the condyle of the working side is called the Bennett movement [Baragar 1984] whereas in the non-working side the angle formed between the sagittal plane and the average path of the non-working condyle as viewed in the horizontal plane during lateral mandibular movements is called the Bennett angle [The Glossary of Prosthodontics Terms 2005, Bennett 1908].

The *functional movements* of the TMJ are mastication, swallowing and speech. They are free movements, this is, they occur within the limits of the dynamic relations–movements of the mandible [Okeson 2007, p.86].

Dynamic occlusion

Dynamic occlusion is defined as the tooth contacts that exist during the movements of the mandible. The movements of the mandible are determined not only by muscles but also by the two TMJs which are referred to as the posterior guidance system and the teeth which are referred to as the anterior guidance system [Kohno 1987, Davies 2001]. When the mandible moves from the centric, some teeth should have contacts, depending on the movement. These teeth then provide the anterior guidance. During laterotrusions the anterior guidance is provided either by the canines or by a group of teeth, while during protrusion the guidance should be provided by the front teeth.

Canine guidance is this dynamic occlusion when the mandible slides laterally and the canines of the working side are the only teeth in contact. The group function refers to this dynamic occlusion when the contacts exist through the bicuspids and/or the molars of the working side during the laterotrusions. Generally, canine guidance is considered more favourable. The root/crown ratio is better than in other teeth, because canines have very long roots. Thus, they are more appropriate to accept the horizontal forces that occur during laterotrusions and, consequently, protect the other teeth from wear [Standlee 1979]. The group function should be considered as an alternative solution when the canines are not considered to be able to play this role. This could happen when the canines have periodontal problems or when they are not positioned in a Class I occlusion, for example when the lateral incisors are missing and space closure is planned [Okeson 2007, p.105- 108, Oltramari 2007]. During protrusion of the mandible the guidance should be provided by the front teeth, in order to disocclude the posterior teeth [Standlee 1979]. The lower incisors should slide on the palatinal surfaces of the upper incisors, providing total disocclusion of the posterior teeth [Oltramari 2007]. In a study of Al-Hiyasat et al. 2004, on untreated children at 14-17 years of age, canine-guided occlusion was found in 57% of the children, while front guidance existed in 78% of the children during protrusion. According to the study of Parnia et al. 2008 involving 50 untreated Angle Class I dental students, the majority (60%) of the subjects had a group function on the working-side for laterotrusions to the right in contrast to the canine protection which was seen in only 17% of the subjects. As for the left side the results were quite similar, group function was found in 51% of the patients and canine guidance in 21%. The relationship between the anterior and posterior guidance is not clear till now and is discussed controversially. According to the findings of Hickey et al. 1963 the pathways of the condyles are influenced by tooth contacts whereas Alsawaf et al. 1994 suggested that there is no influence from the anterior guidance to the posterior guidance. The findings of Pelletier et al. 1990 are in agreement with the findings of Alsawaf.

Another important issue relevant for understanding the movements of the mandible and the condyles is to define the axis of movement.

Condylar reference points

Axiography provides important information about the kinematics of the mandible and the TMJ as the movements of the mandible can be recorded in great accuracy with 6 degrees of freedom recording systems [Reicheneder 2008, Baqaien 2007, Wessling 2003]. In order to analyze the movements of the condyles it is important to choose the reference points that represent the condyles, since during the movements of the mandible the condyles undergo not only translatory but also rotatory movements, resulting in different movement traces for the different condylar points due to the rotatory movements. Thus, the condylar reference point influences the path of the recorded movements. Therefore, it is important to define the reference points [Zwijnenburg 1996, Ćatić 1999]. In literature, different theories have been suggested regarding the condylar reference points. The first one is based on anatomically determined points, namely an arbitrary defined point [Kang 1993]. The second one refers to kinematically determined points, for instance the terminal hinge axis point [Piehslinger 1991, 1993] and the kinematic center [Kohno 1968, 1987].

The terminal hinge axis is an axis around which the condyles rotate during the terminal hinge movement [Weinberg 1959]. It is an easily reproducible point [Piehslinger 1993] and can pass through or near the condyles [Weinberg 1959]. This axis should be used for the reconstruction of mandibular movements in the articulator [Yatabe 1995, Ćatić 1999].

According to Yatabe et al. 1995, 1997, "*the kinematic center is that condylar point for which the opening movement path coincides with the protrusive movement path*". It is minimally influenced by the rotatory component of mandibular movements [Kohno 1968, Yatabe 1995, Zwijnenburg 1996]. However, Gallo et al. 2008 came to the conclusion that the position of the kinematic center as defined in literature [Kohno 1968, Yatabe 1995, Zwijnenburg 1996, Ćatić 1999] is not related to the anatomy of the condyles and the joints and may be located outside of the condyle. They suggest that the traces of the TMJ kinematic center are only to some extent representative of the joint space variation and the movement of the condyles. In their study, Ćatić et al. 1999 found that there is a difference between the findings when using the hinge axis or the kinematic center as reference point. They examined asymptomatic and TMJ symptomatic patients. In asymptomatic patients, the average distance between the hinge axis and the kinematic center was approximately 4.96 mm. In the TMJ symptomatic patients, this distance was even greater, approximately 9.0 mm. They concluded that the kinematic center might be an appropriate reference point in order to record the kinematic variables of the mandible and the condyles. On the other hand, the hinge axis is more adequate for reconstruction of mandibular movements in the articulator.

The arbitrary method has been widely used because it is quite simple and fast [Teteruck 1966, Bernhardt 2003]. What is more, the study of Bernhardt et al. 2003 suggests that the arbitrarily determined reference points are comparable to the kinematic center points and are reliable to use.

2.3. Prenatal – postnatal growth

The TMJ, as a part of the stomatognathic system, develops postnatally in close relation and interaction with the maturation of the chewing and swallowing functions, the growth of the jaw muscles and particularly the growth of the masseter and temporalis, and the development of the dentition. Hinton et al. 1981 suggested that the TMJ during adult life is under constant morphological change, and that these alterations are connected to the dental function. The different parts of the TMJ do not develop at the same time or with the same rhythm [Spuropoulos 1977, Enlow 1992]. Interestingly, during embryonic life a temporary joint exists instead of the TMJ. It is formed by the arch Meckel’s cartilage (cartilage of the first branchial). This temporary joint between Meckel’s cartilage and the skull base is similar to those of non-mammalian creatures [Moffett 1966] and allows small movements [Humphrey 1971]. This joint is not the precursor of the TMJ which develops separately, so for some time the two joints coexist [Moffett 1966, Dixon 1997]. Van der Linden 1987 found that the critical period for the development of the TMJ is at about 7th to 11th weeks. This opinion is shared by other authors like Merida- Velasco et al. 1999, while Furstman et al. 1963 support that the critical period is between the 8th and the 12th week. The anatomy and development of the temporomandibular joint have been widely studied. Several investigations especially into the prenatal development of the human TMJ are available [Van der Linden 1987, Toller 1993, Lee 2001, Wierusz 2004]. According to Merida-Velasco et al. 1999, three phases are identified during prenatal development of the TMJ. The first one is the blastematic stage at about the 7th to 8th week of fertilization. At this time the first development and organization of the condyle, the articular disc and the articular capsule occur. During the 8th week the intramembranous ossification of the temporal squamous bone begins. The second phase occurs during the 9th to 11th week of fertilization, where separating of the joint cavities takes place (cavitation phase). At the same time chondrogenesis of the condyle starts. The third phase is the maturation phase starting at about the 12th week of fertilization. The main events in the formation of the TMJ are already completed by the end of the prenatal period [Moffett 1966].

2.3.1. Condyle

During the 7th week of fertilization a group of cellular mesenchymal tissue is formed around the posterior end of linear trabeculae of the mandible, which is then traced into a fibrous mesenchyme around the Meckel cartilage. During the 8th week the condensed mesenchyme produces a condyle blastema, which from the 9th week produces a secondary fibrous cartilage thus forming the condylar head [Lee 2003, Toller 1993]. Van der Linden et al. 1987 found that the first evidence of a condyle appears between the 9th and the 10th week. The condyle grows upwards and laterally through endochondral ossification. They also found that the initial shape of the condyle is mostly convex. As development proceeds, the cartilage is being replaced by osseous structures, thus contributing to the growth of the mandible. There are many different views regarding the postnatal growth of the condyle. At the age of 6 years the articular layer of the condyle starts to thicken whereas the cartilage layer becomes thinner, actually retaining only half of its dimension at 6 months after birth [Thilander 1976]. Björk 1963 suggests that the condyle does not grow with the same rate throughout the growth period. He found that condylar growth amounts to 3 mm per year during the childhood period, decreases prepuberally, and then increases again to 5.5 mm per year (minimum 4.5 – maximum 8.0 mm) at about the age of 14,5. On the other hand, in a study on treated and untreated patients between 8.5 and 15.5 years of age Baumrind 1992 found that condylar growth remains rather constant. Vertical growth of the condyle was found to be approximately ninefold the horizontal growth [Buschang et al., 1998]. These authors measured the movement of the condylar point and the articulare. The boys showed significantly more total condylar growth than the girls during adolescence. This difference was mainly observed for the vertical growth of the condyle, while no gender differences were found in the horizontal plane. They concluded that condylar growth follows the general growth of the subjects, i.e., it decelerates during childhood, accelerates during adolescence and then decelerates again after the peak of adolescence [Buschang et al., 1999]. Karlo et al. 2010 found that the left-right and the antero-posterior diameter of the condyle increase with age. Boys showed a greater left-right diameter than girls. Their results suggest that both the size and shape of the condyles change during childhood growth. The shape changes from round into oval when transverse images are taken [Karlo et al., 2010].

2.3.2. Fossa and articular eminence

The first evidence of the temporal bone articular fossa occurs during the 7th week. During the 8th week of fertilization begins the intramembranous ossification of the zygomatic process of the squamous part of the temporal bone. By the 13th week of fertilization the morphology of the fossa is already concave [Merida-Velasco 1999]. Its concavity increases even more after the 33rd week [Morimoto 1987]. Many authors have described the postnatal development of the articular fossa and eminence of the TMJ. Björk 1955 estimated that the distance between the nasion and the jaw joint increases by 7.5 mm on average between the age of 12 to 20 years, when the articulare is used as reference point, resulting in posterior and inferior displacement of the fossa. Baumrind et al. 1983 suggests a downward and backward displacement of the glenoid fossa. Agronin et al. 1987 agree with these findings. Their investigation in a large sample of orthodontically treated patients showed a significantly larger posterior displacement of the articulare and the fossa, during development in patients with vertical facial growth patterns. Buschang et al. 1998 found a 1.8–2.1 mm posterior displacement of the fossa and a 1.0–1.8 mm inferior displacement of the fossa during childhood and adolescence growth. The inferior movement of the articulare was significantly greater than that of the condyle, and greater for boys than for girls. During adolescence, the inferior and posterior displacement of the fossa was greater than during childhood. The articular eminence is almost absent or rudimentary at time of birth [Thilander 1976, Wright 1974]. It shows a rapid development during the first 2 years, till the completion of the primary dentition. In the study of Katsavrias et al. 2002 a statistically significant increase in the inclination of the articular eminence was observed. According to this study, the latter has reached 40-50% of its adult size by 2 years of age. At the age of 10 years it shows a mean inclination angle of 70-72% of its final value, whereas at the age of 20 years it has completed 90 to 94,5% of its final size. Interestingly, the articular eminence inclination angle still changes after the growth period, indicating an association with function. According to Nickel et al. 1988, the eminence has reached more than 50% of its final size and morphology at 3 years. The rate of eminence development is high until the age of 3, and then diminishes after the age of 5. The eminence inclination angle is about 25° at 3 years and increases to 45° till the age of 18 years. The eminence inclination angle has a normal value that varies between 30° and 60° and determines the limits of condyle movement. When the angle is smaller than 30° it is considered as flat and when bigger than 60° is considered as steep [Bell 1982 p. 37-80]. Ikai et al. 1997 suggest that a steeper eminence angle indicates a retrusive maxilla or a protrusive mandible. According to Widman et al. 1988 an inverse correlation between the articular eminence angle and the occlusal and mandibular plane exists. In other words, when the steepness of the articular eminence angle increases, the occlusal and mandibular planes show a tendency to become more horizontal, which is observed in the brachycephalic facial type. In another study of Granados 1979 flattening of the articular eminence is suggested when teeth attrition occurs. These findings are also supported by Hinton et al. 1981.

2.3.3. Disc

The articular disc first appears at 7 to 7.5 weeks of fertilization as a horizontal zone of mesenchyme which separates the articular fossa and the condyle [Wong 1985, Van der Linden 1987]. Toller 1993 in his study found that the disc first appears at the 10^{th} week of fertilization. The first signs of collagenous fibers in the disc are seen by 10 to 10.5 weeks and become more pronounced at about the 12^{th} week. At that time, the disc is thin in the central region and is attached to the condyle [Van der Linden 1987, Toller 1993, Wierusz 2004]. Its final fibrous structure is evident at about the 19^{th} to 20^{th} week [Van der Linden 1987]. According to Wierusz 2004, the articular disc is already well formed between the 12^{th} and 14^{th} week of fertilization. The role of the disc is to divide the joint cavity into two smaller cavities in order not to allow direct contact between the condyle and the articular fossa and eminence during the movements of the mandible. It is thinner centrally than peripherally. The findings of Wong et al. 1985 support that the shape of the fetal disc, at the time when delineation is possible, resembles the shape of the adult disc and, therefore, suggested a genetic determination of articular disc shape.

3. Statement of the problem

Potential signs or symptoms of TMJ problems in children, such as the range mandibular movement, should alert the orthodontist that modification or change of the treatment plan may be needed. Especially the maximum mouth-opening capacity should be measured during treatment to monitor the mobility of the mandible. Any functional disturbances should be documented before the onset of treatment. In TMD patients it is even more important to record the function of the TMJ, since underestimating the functional problems might result in worsening. The increasing number of TMD patients who seek orthodontic treatment highlights the need for accurate diagnosis before treatment begins. While a lot of studies were conducted on mandibular kinematics in adults, children have not been so widely investigated. Axiography has been proved to be an important diagnostic tool, as it is a favourable examination, is easily accepted by the patients, requires not so much time and yields exact results regarding not only the maximum range of movement of the mandible (which is also amenable to measurement during clinical examination) but also the kinematic characteristics of the condyles, such as the Bennett angle and the Condylar Path Inclination Angle (HCN).

4. Aim of the study

The aim of this study was to obtain information about the condylar and mandibular kinematic variables of children and adults, to investigate the range of mandibular and condylar movements and to determine whether there is an association of mandibular movements and condylar kinematic variables with specific characteristics of the individuals, such as gender, facial type, body weight and height, overjet and overbite. In addition, any possible differences between the right and left sides will be examined.

5. Subjects and methods

5.1. Subjects

Two groups were examined in this study. The main group (GR 1) comprised 92 children (48 boys and 44 girls) aged 7.2 to 10.6 years, and the control group (GR 2) consisted of 40 adults between 18 and 34.7 years of age.

The main group was examined at two elementary schools, in Regensburg and in Paderborn, Germany. Informed consent with the children's examination was obtained from the parents. The selection of the children was randomised, given parental permission. None of the children had undergone orthodontic treatment. The children showed different types of occlusion, with Class I molar occlusion not required. The controls were also randomised. The control group mainly comprised volunteers from the staff of the Faculty of Dental Science at University of Regensburg Medical Centre, who were informed about the study. All subjects had a normal temporomandibular joint function, except one adult, who reported gnashing of the teeth but no pain. Adult patients with extended restorations, missing teeth, or pain of the TMJ or the stomatognathic system were excluded from the study. Adults with Class I occlusion were also undesired, as the control group was intended to match the children's sample.

5.2 Methods

5.2.1 Clinical examination

The examination comprised two parts, the clinical and the instrumental part. During the clinical examination the following aspects were examined: age, gender, body weight, body height, habitual occlusion, mouth breathing, facial type, overjet, overbite, gnashing of the teeth and TMJ pain. In addition intraoral photos were taken in order to substantiate the clinical findings. The examination sheet is given below.

Untersuchungsbogen JMA

Name, Vorname:

Geburtsdatum:

Geschlecht:

KFO – Behandlung?:

Habituelle Okklusion:

Rechts: 6/6: 3 III/3 III:

Links: 6/6: 3 III/3 III:

Wechselgebissphase (frühe, späte, Ruhephase):

Angle Klassifikation:

Overjet (sag.):

Overbite (vert.):

Knirscher?:

CMD – Kurzbefund:

Kiefergelenkschmerzen?

Okklusale Geräusche?

Mundöffnung asymmetrisch?

Fazialer Typ (dolichofazial, brachyfazial, normofazial):

Gewicht:

Größe:

Figure 1: The examination sheet as expressed in German.

Examination sheet JMA

Name, first name:
Date of Birth:
Gender:
Orthodontics - treatment?

Habitual occlusion:
Right: 6/6: 3 III/3 III:
Links: 6/6: 3 III/3 III:
Mixed dentition stage (early, late, intermediate phase):
Angle Classification:
Overjet (sag.):
Overbite (vert):
Gnashing of teeth?

CMD - symptoms:
Temporomandibular joint pain?
Occlusal sounds?
Asymmetry during mouth-opening?
Facial type (dolichofacial, brachyfacial, normofacial):

Weight:
Size:

Figure 2: The examination sheet translated in English.

5.2.2 Instrumental examination

Set-up of the JMA system

The instrumental examination of TMJ function and the mandibular movements was performed using the JMA System (Ver. 10.05.03, Jaw Motion Analyzer, zebris

Medical GmbH, Isny, Germany). Current technology allows accurate recording of the mandibular movements in three dimensions. The zebris Jaw Measurement Analysis System enables contactless 3D recording with six degrees of freedom at a sampling frequency of 75 Hz. Its principle is based on measuring the travel time of ultrasound impulses, i.e., the real-time latency period of sequentially transmitted ultrasound pulses at a frequency of 40 Hz, between a sending device (fastened on the front teeth of the mandible) and receiver device mounted to the forehead. The movements are recorded at an accuracy of 0.1 mm in the incisal region and 0.2 to 0.3mm in the condylar region (Hugger et al., 2001). The sensors are connected to a computer through a basic unit with power pack together with a table-mounted or floor stand. (http://www.zebris.de/english/medizin/medizin-3dmesssysteme-cms20s.php? navan-chor=1010003). The JMA system is supported by the software programme WinJaw Version 10.05.03 [www.zebris.de 26.06.2010] which records the movements of the mandible. The examination results are shown on a computer display (Fig. 3).

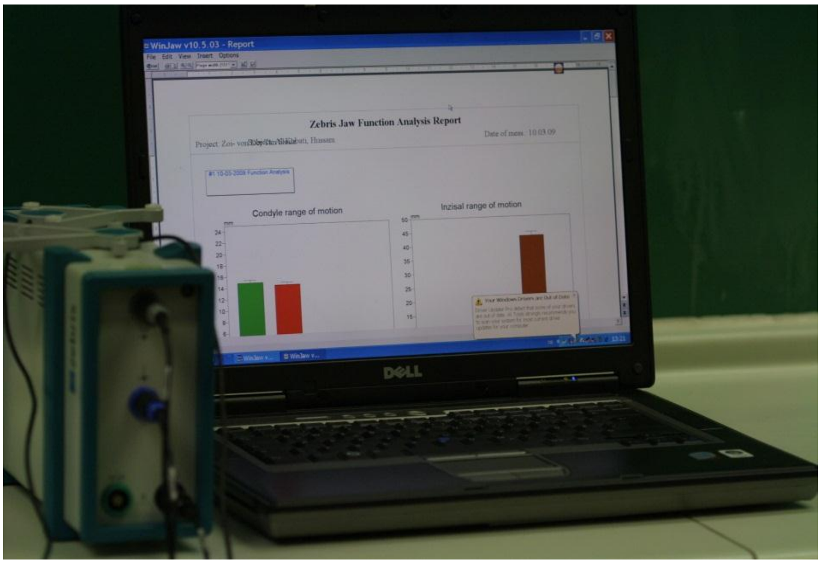


Figure 3: The JMA system connected to a computer. Examination results are shown on the display.

The JMA device consists of a face-bow where the plastic frame with the four integrated receiver sensors is fixed, and of a paraocclusal metal bite fork where the three-sending-sensors frame is mounted (Figs. 4,5). The sending sensor is fastened to the bite fork with a magnetic holder and is, therefore, extremely light (approx. 40 gr) in order not to affect the movements of the mandible.

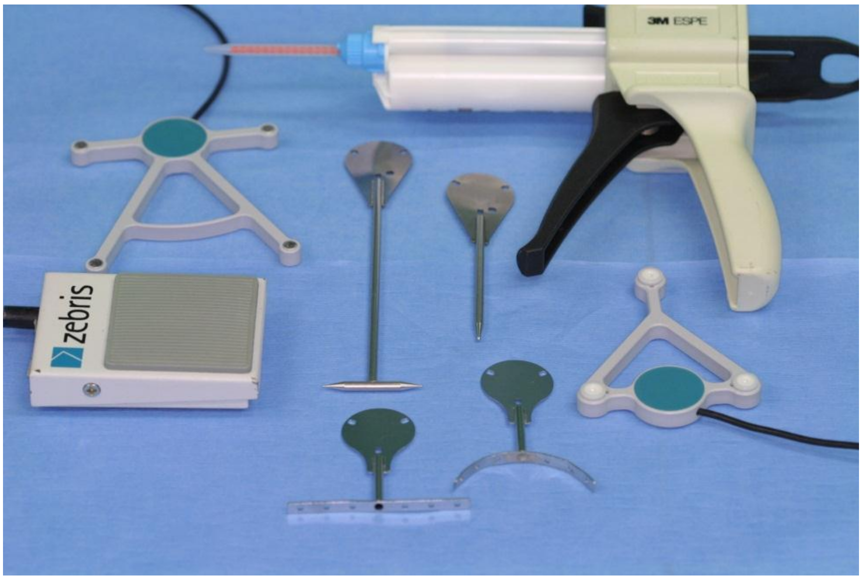


Figure 4: The bite forks, the two sensors, the two pointers, the pedal and the composite.

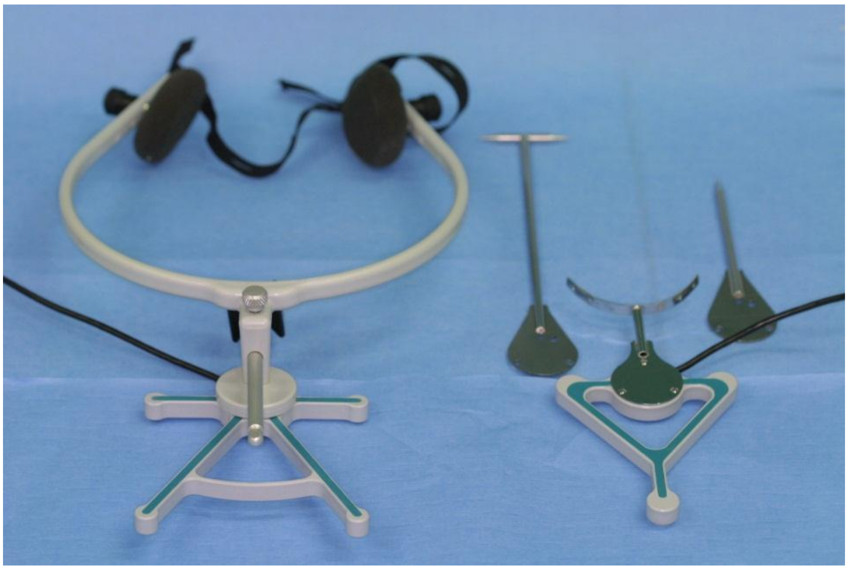


Figure 5: The receiving sensor attached to the face-bow and the sending sensor attached to the bite fork. The two pointers should be attached to the sending sensor, before attaching it to the bite fork, which is fastened in mouth, in order to define the points for the reference plane of the movement and the arbitrary axis.

The receiving frame was fastened to the face-bow through a magnetic holder. Positioning of the face-bow is shown in Figure 6.

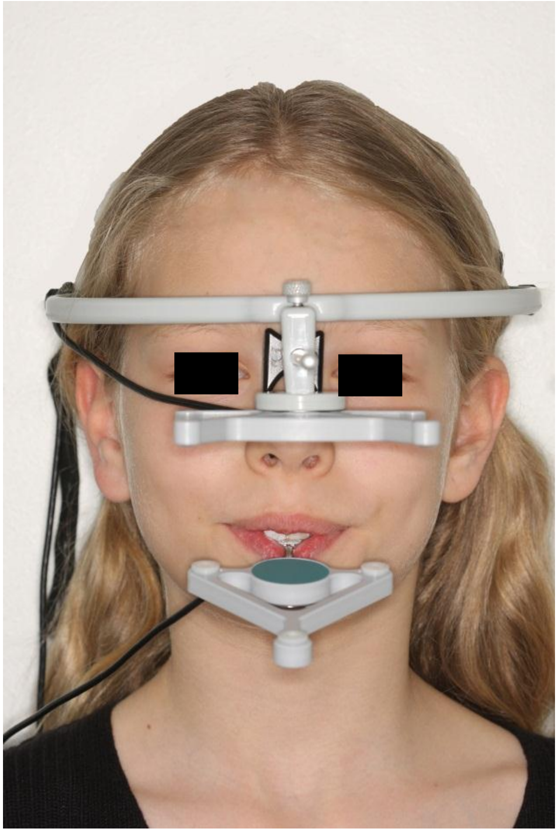


Figure 6a: En face photo of a subject with the device positioned on the head.

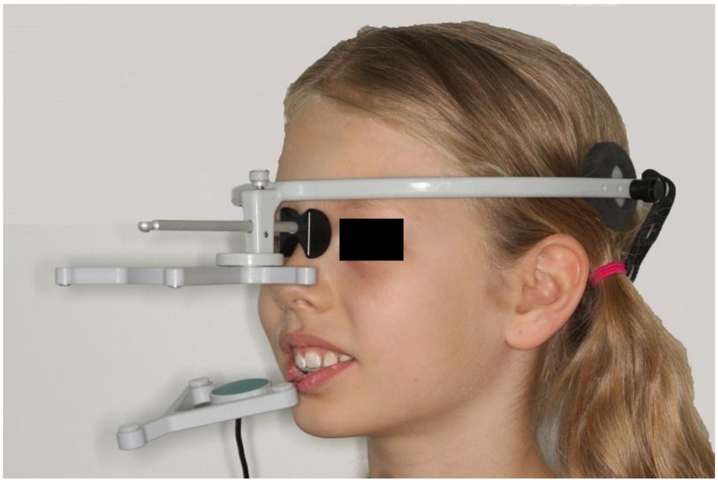


Figure 6b: Photo of the same subject taken at an angle of 45° on the left side.

The paraocclusal bite fork (Fig. 7) was adapted to the labial surfaces of the lower front teeth of the subjects and then individualized with temporary composite, as recommended by the manufacturer (Protemp ®). It was then bonded on the lower teeth with acrylic adhesive (Cyano-Veneer®). The bite fork should not disturb functional activity and maximum intercuspation, but should also be as far as possible from the gingiva (Fig. 8).

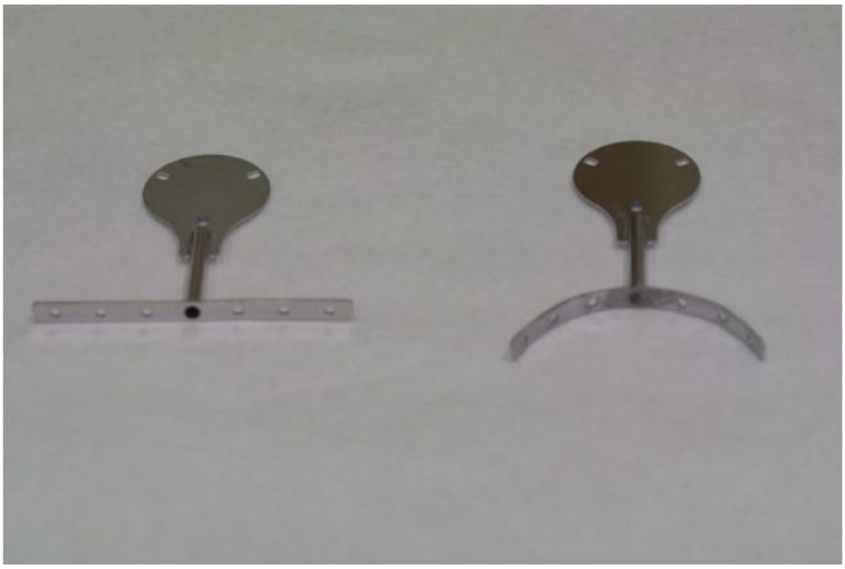


Figure 7: The bite fork. On the left: bite fork as delivered from the manufacturer. On the right: adapted to the lower labial surfaces of the subject, before individualizing with composite.

Figure 8a: Intraoral photo.

Figure 8b: Intraoral photo. The bite fork fastened on the labial surfaces of the anterior lower teeth. It should not interfere while recording the movements: **a.** occlusal view; **b.** frontal-inferior view.

The recorded movements were maximum opening, maximum protrusion, left laterotrusion, right laterotrusion, Posselt frontally and Posselt sagittally. Each movement was repeated twice in order to ensure measurement accuracy and reproducibility. The subjects were asked to sit in an upright and relaxed position, looking straight ahead. Each movement should start and end in maximum intercuspation, and the subjects should perform each movement toothguided and without manipulation. At the end of the examination, the bite fork was easily removed from the labial surfaces of the lower teeth, through a slight movement of the bite fork in the vertical plane. Then the remaining composite or adhesive was removed from the labial surfaces of the teeth with a scaler and damp cotton pads. The device had also been previously tested and proven capable of analysing complex jaw movements accurately and with a very good degree of reproducibility [Hugger 2001, Wessling 2000].

Instrumental functional analysis

The purpose of instrumental functional analysis is to select information about the condylar and the mandible kinematic variables which represent the function of the mandible and the TMJ. Instrumental functional analysis is even more important in patients with temporomandibular disorders or those who will undergo extended restorations.

In order to record the movements it was first necessary to define the reference plane which was chosen to be the the axial-orbital plane. In this study, the arbitrary axis was used as the axis of the movement. We used the “ear tragus superior” point in order to define the axis of the condyles. The input was obtained arbitrarily by directly touching the skin points using the T-pointer. The left ear tragus superior was recorded first and followed by the right one. Then, the position of the axis was calculated by the software program using special algorithms according to the original paper by Reiber and Dickbertel 1988. The right orbital point was used for definition of the reference plane. The input for this point was also done arbitrarily using the short-pointer.

A report on functional instrumental analysis is automatically provided for each examination (Fig. 9). The Winjaw Software Program provides the opportunity to evaluate the incisal and the condylar range of movements. To start with, the incisal range of movement is calculated as the linear distances of the incisal point movements (starting and end position) during maximum mouth-opening and laterotrusion to the right and to the left. Maximum mouth-opening is measured in the vertical plane as the maximum difference between the starting and the end position of the incisor point. In the horizontal plane are measured the lateral movements. As the subjects were asked to repeat every movement twice, the estimated means represent the average values of both recordings. This applies to all movements. The condylar range of movement is calculated. Retrusion of the condyles is calculated from the sagittal movement section of ipsilateral laterotrusion. Length of the condylar path in the sagittal plane during maximum opening is measured as the curvilinear distance in mm. The zero position is determined in maximum intercuspation. The standard deviation is also shown as a figure value and as a line graph. All values are measured in millimetres.

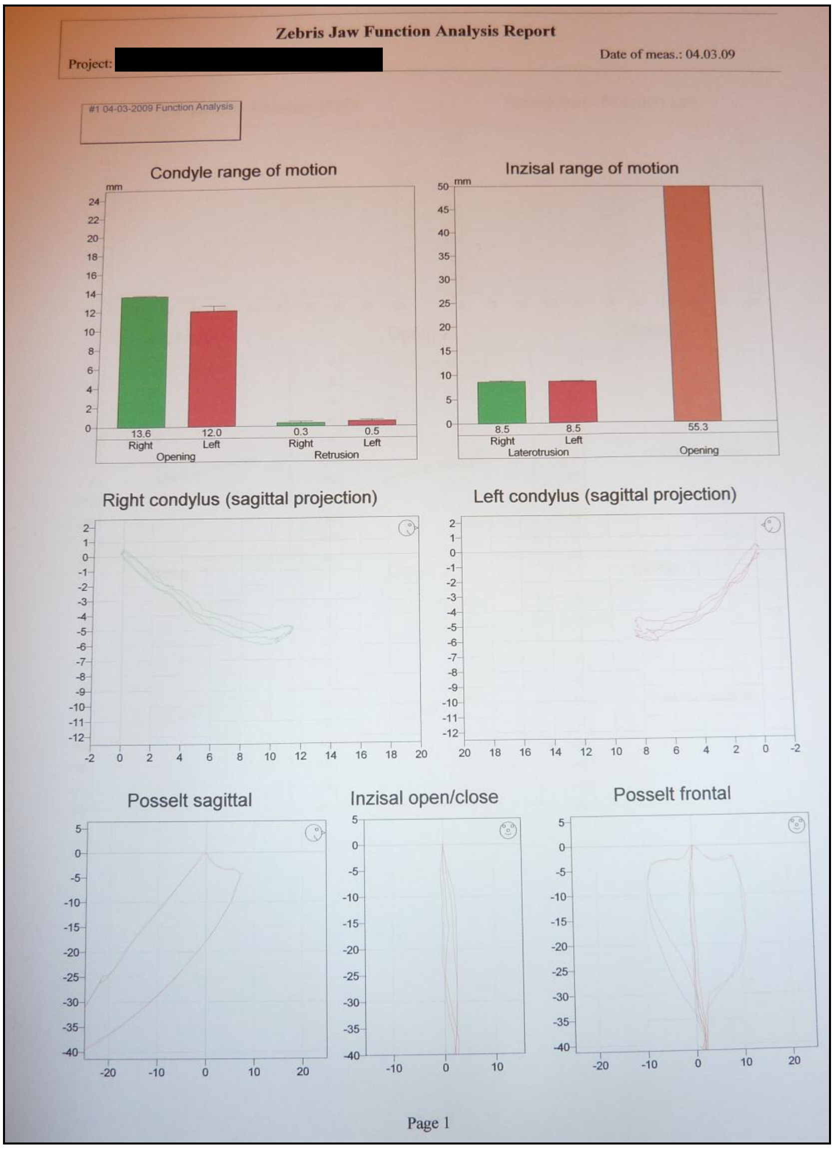


Figure 9a: First page of the functional analysis report of a subject, provided from the WinJaw Software program.

Apart from the linear measurements the Winjaw Software Program enables estimation of the angular kinematic variables of the condyles, this is the condylar path inclination angle in the sagittal and the Bennett angle in the horizontal plane. The angle values of the condylar path inclination angle (HCN) and the Bennett angle (BEN) can be followed at millimetre increments. These values are estimated from the average path of the two protrusions at the same side and the two laterotrusions of the opposite side respectively.

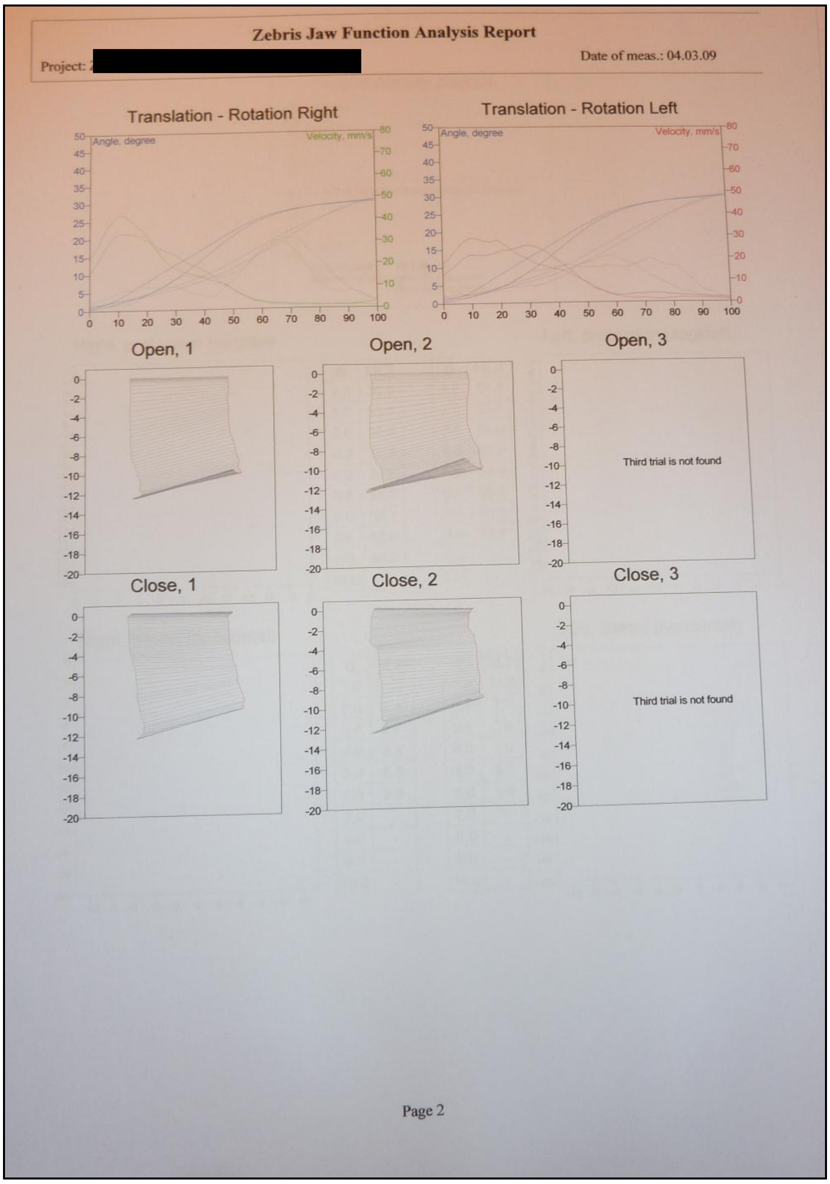
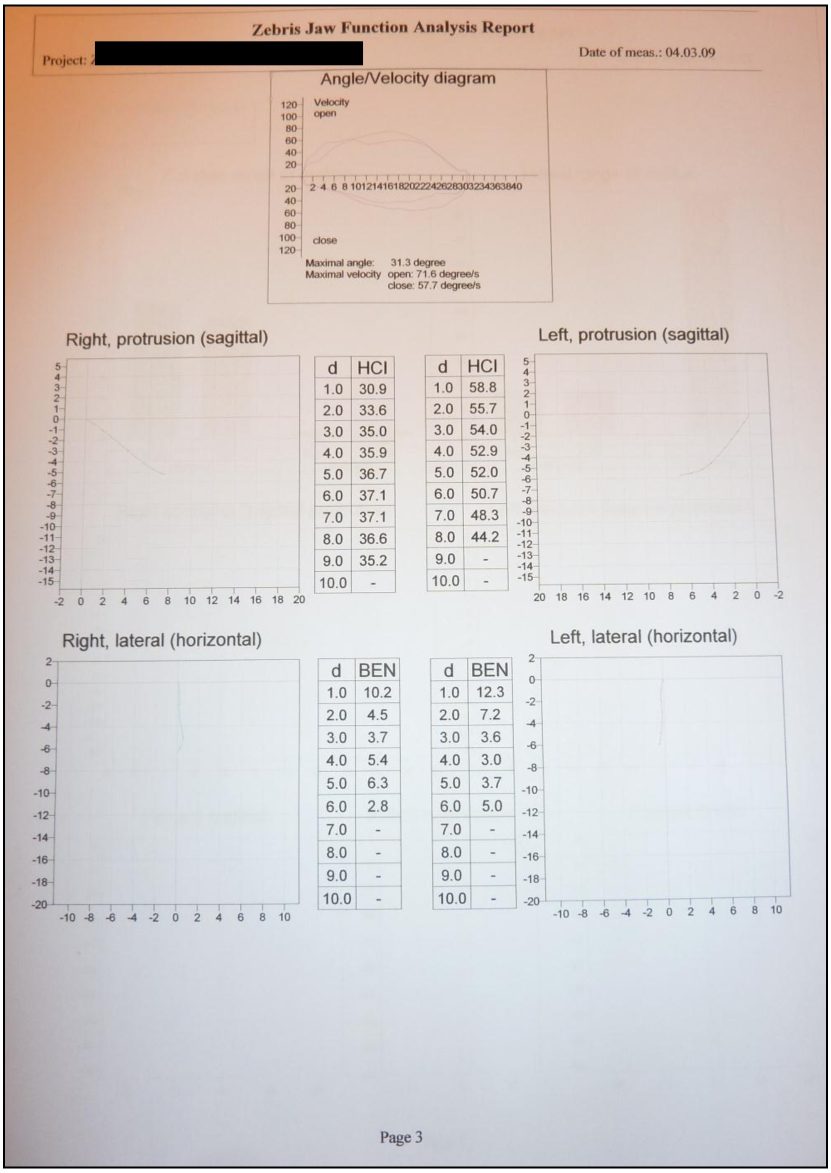


Figure 9b: Second page of the functional analysis report of a subject, provided from the WinJaw Software program.

Furthermore, the software program allows assessing if the function of the two condyles is synchronised. Diagrams show phase displays of the intercondylar axis of the first two opening and closing movements. In addition, the protrusion velocities of the intercondylar axis in opening and closing movements are shown.

Subjects are given the opportunity to watch their own movements reproduced by a 3D animation model. The orthodontist can easily explain any disturbances of the recorded movements and has access to the measurements of each patient. The examiner can also export the results and compare them using statistical analysis software.



Zebris Jaw Function Analysis Report

Project: [redacted]

Date of meas.: 04.03.09

Angle/Velocity diagram

Velocity open

close

Maximal angle: 31.3 degree
Maximal velocity open: 71.6 degree/s
close: 57.7 degree/s

Right, protrusion (sagittal)

d	HCI
1.0	30.9
2.0	33.6
3.0	35.0
4.0	35.9
5.0	36.7
6.0	37.1
7.0	37.1
8.0	36.6
9.0	35.2
10.0	-

Left, protrusion (sagittal)

d	HCI
1.0	58.8
2.0	55.7
3.0	54.0
4.0	52.9
5.0	52.0
6.0	50.7
7.0	48.3
8.0	44.2
9.0	-
10.0	-

Right, lateral (horizontal)

d	BEN
1.0	10.2
2.0	4.5
3.0	3.7
4.0	5.4
5.0	6.3
6.0	2.8
7.0	-
8.0	-
9.0	-
10.0	-

Left, lateral (horizontal)

d	BEN
1.0	12.3
2.0	7.2
3.0	3.6
4.0	3.0
5.0	3.7
6.0	5.0
7.0	-
8.0	-
9.0	-
10.0	-

Page 3

Figure 9c: Third page of the functional analysis report of a subject, provided from the WinJaw Software program.

5.3 Data analysis

Statistical data analysis was carried out with the Programm SPSS for Windows, SPSS Release 17 (SPSS Inc., Chicago, IL, USA). The distribution of the recorded data was presented descriptively using the parameters mean, median, standard deviation, minimum and maximum.

Categorical data (facial type, gender) were evaluated using one-way analysis of variance (ANOVA), with facial type and gender considered as independent variables (group factors). Significance was tested using the F distribution, F values with $p < 0.05$ were considered as significant.

Associations of metric variables such as body height and weight, overjet and overbite with the dependent kinematic variables were described using Spearman's rank correlation rho which is equivalent to Pearson's product-moment correlation r. Correlations are positive when both variables move in the same direction, and negative for opposite directions. The magnitude of correlations varies between 0 (no correlation) and 1 (full connection). Correlations with $p < 0.05$ are considered to be significant.

In order to adjust for multiple significance testing, a correction after Bonferroni (α/n_{tests}) was used establishing a rule-of-thumb significance level of $\alpha_{corr} = 0.005$.

6. Results

6.1. Gender

Overview

An overview of the results obtained for gender effects is given below in Tables 1-4.

Table 1: Descriptive statistics of the kinematic variables of the mandible and the condyles of the children according to gender. Modified SPSS Table.

Report

GR	GENDER		OP_C_RI	OP_C_LE	RET_C_RI	RET_C_LE	LAT_IN_RI	LAT_IN_LE	OP_IN	HCN_3_RI	HCN_3_LE	HCN_5_RI	HCN_5_LE	BEN_3_RI	BEN_3_LE	BEN_5_RI	BEN_5_LE
1	b	Mean	16,367	16,833	0,229	0,258	9,358	9,617	47,723	35,667	35,842	33,281	33,806	10,748	11,079	8,454	8,352
		Std. Deviation	3,225	3,859	0,429	0,412	2,481	2,005	6,389	10,905	11,842	8,482	9,039	4,927	5,317	3,512	4,045
		Median	16,65	16,7	5,00E-02	0,1	9,4	9,8	47,35	37,35	38,85	33	34,35	10,75	10,4	8,3	7,8
		Minimum	10	8,9	0	0	3,3	4,2	35,4	-3,3	-12,2	12,2	7	1	1,3	1,9	1,6
		Maximum	28	32,6	2,1	2,3	13,8	13,4	60,8	52,5	55	49,3	51	21,5	25,8	16,2	20,7
	g	Mean	16,489	17,402	0,216	0,243	9,905	9,68	45,652	37,398	36,505	35,411	34,179	12,543	10,568	9,97	8,489
		Std. Deviation	4,038	3,785	0,518	0,405	1,985	2,45	6,867	9,424	9,627	7,584	8,147	6,242	5,549	4,163	4,441
		Median	16,65	17,5	0	0,1	9,95	9,85	45	38,5	36,2	35,8	36,3	11,35	9,85	9,35	7,55
		Minimum	6,8	7,3	0	0	4	0,4	28	10,9	16,7	17,9	16,6	1,3	1,5	1,2	2
		Maximum	25,5	26,1	3,2	2,2	15,1	15,1	59,2	55,4	57,6	52,1	51,5	26,5	24,8	21,4	18,6
	Total	Mean	16,425	17,105	0,223	0,251	9,62	9,647	46,733	36,495	36,159	34,3	33,982	11,607	10,835	9,179	8,417
		Std. Deviation	3,617	3,813	0,471	0,407	2,262	2,216	6,667	10,205	10,786	8,093	8,583	5,636	5,405	3,891	4,216
		Median	16,65	17,05	0	0,1	9,8	9,8	46,25	37,75	38,65	34,7	35,4	11,15	10,05	8,8	7,65
		Minimum	6,8	7,3	0	0	3,3	0,4	28	-3,3	-12,2	12,2	7	1	1,3	1,2	1,6
		Maximum	28	32,6	3,2	2,3	15,1	15,1	60,8	55,4	57,6	52,1	51,5	26,5	25,8	21,4	20,7

Table 2: Descriptive statistics of the kinematic variables of the mandible and the condyles of the adults according to gender. Modified SPSS Table.

Report

GR	GENDER		OP_C_RI	OP_C_LE	RET_C_RI	RET_C_LE	LAT_IN_RI	LAT_IN_LE	OP_IN	HCN_3_RI	HCN_3_LE	HCN_5_RI	HCN_5_LE	BEN_3_RI	BEN_3_LE	BEN_5_RI	BEN_5_LE
2	m	Mean	17,33	19,15	0,135	0,12	9,735	9,305	52,15	42,93	45,768	40,685	43,495	12,7	13,585	11,29	11,37
		Std. Deviation	5,295	6,074	0,163	0,154	2,254	2,424	7,502	10,057	10,912	9,21	9,975	3,817	4,47	3,463	3,956
		Median	18,4	20,95	0,1	0,1	9,3	8,3	53,65	42,7	48,1	40,6	45,75	12,45	13,05	11,4	11,85
		Minimum	4,9	7	0	0	6,7	6,8	37,9	22,2	18,5	20,4	19,9	3,6	5,6	2,5	2,9
		Maximum	26,2	26,8	0,6	0,5	13,9	14,1	64,6	58,4	61,6	55,2	57	18,1	26,4	16,8	20,2
	w	Mean	17,695	18,315	0,225	0,185	8,105	8,925	54,91	48,795	47,91	45,885	45,57	18,585	16,69	15,06	14,435
		Std. Deviation	3,589	3,149	0,461	0,291	2,267	2,729	6,067	12,747	10,975	11,238	10,249	8,546	7,444	7,626	7,401
		Median	17,75	19	0	0,1	8,3	8,1	55,35	49,95	49,45	48,1	45,5	16,85	16,35	13,05	13,55
		Minimum	11,8	12,8	0	0	3,2	3,6	43,3	21,7	27,8	20,9	25,3	8,3	3,4	5,9	4,2
		Maximum	23,3	22,5	1,7	1	13,1	13	66,8	65,1	64,6	61,3	59,7	38,5	33,3	36,4	35,9
	Total	Mean	17,512	18,732	0,18	0,153	8,92	9,115	53,53	45,863	46,867	43,285	44,532	15,643	15,138	13,175	12,903
		Std. Deviation	4,468	4,794	0,344	0,232	2,379	2,555	6,878	11,716	10,854	10,478	10,037	7,181	6,261	6,15	6,059
		Median	18,15	20	0,1	0,1	8,5	8,15	54,4	46,1	48,5	43,3	45,5	14,45	14,45	11,8	12,5
		Minimum	4,9	7	0	0	3,2	3,6	37,9	21,7	18,5	20,4	19,9	3,6	3,4	2,5	2,9
		Maximum	26,2	26,8	1,7	1	13,9	14,1	66,8	65,1	64,6	61,3	59,7	38,5	33,3	36,4	35,9

Table 3: AN0VA table of analysis of the kinematic variables of the mandible and the condyles of the children according to gender. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni correction at 0.005 level.

ANOVA Table								
GR				Sum of Squares	df	Mean Square	F	Sig.
1	OP_C_RI * GENDER	Between Groups	(Combined)	0,342	1	0,342	0,026	0,873
		Within Groups		1189,871	90	13,221		
		Total		1190,213	91			
	OP_C_LE * GENDER	Between Groups	(Combined)	7,431	1	7,431	0,508	0,478
		Within Groups		1315,836	90	14,62		
		Total		1323,267	91			
	RET_C_RI * GENDER	Between Groups	(Combined)	0,004	1	0,004	0,018	0,894
		Within Groups		20,218	90	0,225		
		Total		20,222	91			
	RET_C_LE * GENDER	Between Groups	(Combined)	0,005	1	0,005	0,031	0,86
		Within Groups		15,065	90	0,167		
		Total		15,07	91			
	LAT_IN_RI * GENDER	Between Groups	(Combined)	6,849	1	6,849	1,344	0,249
		Within Groups		458,756	90	5,097		
		Total		465,605	91			
	LAT_IN_LE* GENDER	Between Groups	(Combined)	0,091	1	0,091	0,018	0,893
		Within Groups		446,958	90	4,966		
		Total		447,049	91			
	OP_IN * GENDER	Between Groups	(Combined)	98,428	1	98,428	2,245	0,138
		Within Groups		3945,995	90	43,844		
		Total		4044,422	91			
	HCN_3_RI * GENDER	Between Groups	(Combined)	68,791	1	68,791	0,658	0,419
		Within Groups		9408,076	90	104,534		
		Total		9476,867	91			
	HCN_3_LE * GENDER	Between Groups	(Combined)	10,087	1	10,087	0,086	0,77
		Within Groups		10576,636	90	117,518		
		Total		10586,723	91			
	HCN_5_RI * GENDER	Between Groups	(Combined)	104,163	1	104,163	1,601	0,209
		Within Groups		5855,297	90	65,059		
		Total		5959,46	91			
	HCN_5_LE * GENDER	Between Groups	(Combined)	3,153	1	3,153	0,042	0,837
		Within Groups		6627,699	89	74,469		
		Total		6630,852	90			
	BEN_3_RI * GENDER	Between Groups	(Combined)	73,988	1	73,988	2,365	0,128
		Within Groups		2816,188	90	31,291		
		Total		2890,176	91			
	BEN_3_LE * GENDER	Between Groups	(Combined)	5,994	1	5,994	0,203	0,653
		Within Groups		2652,515	90	29,472		
		Total		2658,509	91			
	BEN_5_RI * GENDER	Between Groups	(Combined)	52,78	1	52,78	3,585	0,062
		Within Groups		1325,051	90	14,723		
		Total		1377,831	91			
	BEN_5_LE * GENDER	Between Groups	(Combined)	0,428	1	0,428	0,024	0,878
		Within Groups		1617,244	90	17,969		
		Total		1617,672	91			

Table 4: AN0VA table of analysis of the kinematic variables of the mandible and the condyles of the adults according to gender. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni correction at 0.005 level.

ANOVA Table

GR				Sum of Squares	df	Mean Square	F	Sig.
2	OP_C_RI * GENDER	Between Groups	(Combined)	1,332	1	1,332	0,065	0,8
		Within Groups		777,392	38	20,458		
		Total		778,724	39			
	OP_C_LE * GENDER	Between Groups	(Combined)	6,972	1	6,972	0,298	0,588
		Within Groups		889,456	38	23,407		
		Total		896,428	39			
	RET_C_RI * GENDER	Between Groups	(Combined)	0,081	1	0,081	0,678	0,416
		Within Groups		4,543	38	0,12		
		Total		4,624	39			
	RET_C_LE * GENDER	Between Groups	(Combined)	0,042	1	0,042	0,78	0,383
		Within Groups		2,058	38	0,054		
		Total		2,1	39			
	LAT_IN_RI * GENDER	Between Groups	(Combined)	26,569	1	26,569	5,199	0,028
		Within Groups		194,195	38	5,11		
		Total		220,764	39			
	LAT_IN_LE* GENDER	Between Groups	(Combined)	1,444	1	1,444	0,217	0,644
		Within Groups		253,167	38	6,662		
		Total		254,611	39			
	OP_IN * GENDER	Between Groups	(Combined)	76,176	1	76,176	1,637	0,209
		Within Groups		1768,628	38	46,543		
		Total		1844,804	39			
	HCN_3_RI * GENDER	Between Groups	(Combined)	343,982	1	343,982	2,61	0,114
		Within Groups		5008,972	38	131,815		
		Total		5352,954	39			
	HCN_3_LE * GENDER	Between Groups	(Combined)	44,688	1	44,688	0,373	0,545
		Within Groups		4431,939	37	119,782		
		Total		4476,627	38			
	HCN_5_RI * GENDER	Between Groups	(Combined)	270,4	1	270,4	2,562	0,118
		Within Groups		4011,071	38	105,555		
		Total		4281,471	39			
	HCN_5_LE * GENDER	Between Groups	(Combined)	43,056	1	43,056	0,421	0,52
		Within Groups		3886,192	38	102,268		
		Total		3929,248	39			
	BEN_3_RI * GENDER	Between Groups	(Combined)	346,332	1	346,332	7,907	0,008
		Within Groups		1664,525	38	43,803		
		Total		2010,858	39			
	BEN_3_LE * GENDER	Between Groups	(Combined)	96,41	1	96,41	2,558	0,118
		Within Groups		1432,384	38	37,694		
		Total		1528,794	39			
	BEN_5_RI * GENDER	Between Groups	(Combined)	142,129	1	142,129	4,052	0,051
		Within Groups		1332,806	38	35,074		
		Total		1474,935	39			
	BEN_5_LE * GENDER	Between Groups	(Combined)	93,942	1	93,942	2,668	0,111
		Within Groups		1337,988	38	35,21		
		Total		1431,93	39			

Opening of the right condyle

The results for the opening movement for the right condyle ranged between 4.9 mm and 26.2 mm for the men and 11.8 mm and 23.3 mm for the women. Although the women seem to have a more restricted range of movement for the right condyle, the mean value was similar for both groups. In the children group, the values ranged between 10.0 mm and 28.0 mm for the boys and 6.8 mm and 25.5 mm for the girls. The mean values, though, were similar also for the children. There were no significant differences for both groups.

Opening of the left condyle

The readings for the opening movement for the left condyle ranged between 7.0 mm and 26.8 mm for the men and 12.8 mm and 22.5 mm for the women. In the children the respective values were 8.9 mm and 32.6 mm for the boys and 7.3 mm and 26.1 mm for the girls. The girls seem to have a more restricted range of movement for the left condyle, too. The mean values for both the children and the adult groups were slightly higher than the mean values for the right condyle. There were also no significant results.

Retrusion of the right condyle

For the children group, the mean values are quite similar between the genders, 0.23 mm for the boys and 0.22 mm for the girls. The women appear to have a greater retrusion capacity than the men, with a mean value of 0.23 mm vs 0.14 mm. Yet, the results were not significant for both groups.

Retrusion of the left condyle

No significant differences were observed in the children. The mean value was 0.26 mm for the boys and 0.24 mm for the girls. The women also appeared to have a greater retrusion capacity of the left condyle than the men, with a mean value of 0.19 mm vs 0.12 mm. For the left condyle, the difference was even smaller between the two subgroups and, hence, there is no significant difference.

Laterotrusion to the right

For laterotrusion to the right, a significant gender difference was established in the adults. Mean values were 9.74 mm for the men and 8.11 mm for the women. The women showed a more restricted laterotrusion to the right than the men. Contrary to the adults, the children displayed no significant association of the laterotrusion to the right with gender. The mean measurements were 9.36 mm for the boys and 9.91 mm for the girls. After Bonferroni's correction, there were no significant results.

Laterotrusion to the left

For laterotrusion to the left, no significant results were found for both children and adults. Mean values were 9.31 mm for the men and 8.93 mm for the women. Laterotrusion in the women was also more restricted. The mean measurements for the children were 9.62 mm for the boys and 9.68 mm for the girls.

Mouth-opening

The mean measurements in the children were 47.72 mm for the boys and 45.65 mm for the girls. The boys showed a minimum value of 35.4 mm and a maximum one of

60.8 mm. The recorded measurements in the girls were 28.0 mm and 59.2 mm respectively. The mean measurements in the adults group were 52.15 mm for the men and 54.91 mm for the women. The minimum opening movement was 37.9 mm for the men and 43.3 mm for the women, while the maximum opening movement was 64.6 mm for the men and 66.8 mm for the women. The ANOVA revealed no significant difference for mouth-opening depending on gender, either for the children's group or for the adult group. The children, though, showed a more restricted range of motion than the adults.

HCN of the right condyle at 3mm and at 5mm

The condylar path inclination angle and the Bennett angle were measured at a protrusive path of 3 and 5 mm. These measurements are considered to be reliable as they can be exactly recorded (Reicheneder 2008, Ingervall 1974). According to Baqaien, the condylar path inclination angle can also be calculated stepwise for each millimeter distance, for the first 10 mm of protrusive tracing path on both sides, and then a single mean value may be calculated. Though, we preferred the first way in order to achieve more exact results. For condylar path inclination, results were not significant in the children and the adult group. The mean measurements recorded in all subgroups were smaller for the protrusive path of 5 mm than for the 3 mm protrusive path. The girls and women showed greater mean values of the condylar path inclination of the right condyle than the boys and men respectively. The estimated mean values of the boys were 35.66° at the first 3 mm of protrusive movement and 33.28° at the first 5 mm of protrusive movement and, accordingly, 37.40° and 35.41° for the girls. The mean values for the women were 48.80° at the first 3 mm of protrusive movement and 45.89° at the first 5 mm of protrusive movement, while for the men these values were 42.93° and 40.69° respectively.

HCN of the left condyle at 3 mm and at 5 mm

For the left condyle, the condylar path inclination was also not significantly related to gender for both groups. Like for the right condyle, the mean measurements recorded in all subgroups were smaller for the protrusive path of 5 mm than for the 3 mm protrusive path. The girls and women again showed a greater condylar path inclination of the left condyle than boys and men, with mean values at the first 3 mm of protrusive movement 36.51° for the girls and 47.91° for the women compared to 35.84° for the boys and 45.77° for the men. At the first 5 mm the respective values were 34.18° for the girls and 45.570° for the women in contrast to 33.81° for the boys and 43.50° for the men.

Bennett angle of the right condyle at 3 mm and at 5 mm

An association between the Bennett angle of the right condyle and gender was found in the adults' group only for measurement at 3 mm of laterotrusion. Using the Bonferroni correction, however, results were insignificant in both the children and the adult groups. The mean measurements recorded for all subgroups were smaller at the first 5 mm of laterotrusion than at the 3 mm. For the female groups a larger Bennett angle was assessed.

Bennett angle of the left condyle at 3 mm and at 5 mm

Contrary to the right Bennett angle, no significant results were obtained on the left side for both groups. The women's left Bennett angle was greater than the men's one, whereas the boys showed a greater value than the girls at the first 3 mm of laterotrusion. The mean measurements recorded were also smaller for laterotrusion at the first 5 mm than for the first 3 mm in both the children and the adults.

6.2. Facial type

Overview

An overview of the results obtained for facial type effects is given in Tables 5-8.

Table 5: Descriptive statistics of the kinematic variables of the mandible and the condyles of the children according to facial type. Modified SPSS Table.

Report

GR	FACIAL TYPE		OP_C_RI	OP_C_LE	RET_C_RI	RET_C_LE	LAT_IN_RI	LAT_IN_LE	OP_IN	HCN_3_RI	HCN_3_LE	HCN_5_RI	HCN_5_LE	BEN_3_RI	BEN_3_LE	BEN_5_RI	BEN_5_LE
1	dolicho	Mean	16,123	17,132	8,64E-02	0,109	9,341	9,159	47,055	34,477	32,455	32,959	32,341	11,65	11,073	9,086	8,191
		Std. Deviation	3,398	3,394	0,152	0,202	2,092	2,566	6,163	11,818	13,838	8,319	9,302	5,742	4,947	3,734	3,86
		Median	15,5	16,65	0	0	9,45	9,45	46,05	34,65	34,15	32,5	33	11,15	9,2	7,75	7,4
		Minimum	10,7	11,5	0	0	4,8	0,4	36,4	-3,3	-12,2	12,2	7	1,9	1,5	4,1	2,1
		Maximum	25,5	26,1	0,6	0,7	12,4	12,6	59,2	51,1	50	47,5	45,6	25,2	18,7	17,3	16,9
	brachy	Mean	17,084	17,832	0,242	0,268	9,858	9,753	46,258	36,679	35,816	35,047	33,195	12,179	10,679	8,7	8,747
		Std. Deviation	4,783	5,097	0,273	0,263	2,894	2,358	8,661	12,583	12,336	9,307	9,843	4,708	5,262	3,423	4,353
		Median	17,3	17,5	0,2	0,2	9,6	10,3	48,2	39,4	34,5	34,5	34,2	11,4	9,9	9,2	7,6
		Minimum	6,8	7,3	0	0	4	5,7	28	10,9	16,7	18,9	16,6	4,1	2,6	1,2	2
		Maximum	28	32,6	0,8	0,9	15,1	13,5	57,2	55,4	57,6	52,1	51,5	21	24,8	14,6	18,6
	normo	Mean	16,31	16,824	0,275	0,306	9,651	9,818	46,771	37,296	37,884	34,6	35,004	11,375	10,79	9,398	8,392
		Std. Deviation	3,24	3,463	0,597	0,497	2,098	2,009	6,148	8,451	8,21	7,606	7,755	5,983	5,735	4,164	4,383
		Median	16,8	17,2	0	0,1	10	9,8	45,7	38,3	38,9	35,4	36,4	10,8	10,5	8,9	7,9
		Minimum	7,4	8	0	0	3,3	4,2	34,9	17,2	17,4	14,6	12	1	1,3	1,9	1,6
		Maximum	23,5	24,8	3,2	2,3	13,5	15,1	60,8	52,5	55	49,3	51	26,5	25,8	21,4	20,7
	Total	Mean	16,425	17,105	0,223	0,251	9,62	9,647	46,733	36,495	36,159	34,3	33,982	11,607	10,835	9,179	8,417
		Std. Deviation	3,617	3,813	0,471	0,407	2,262	2,216	6,667	10,205	10,786	8,093	8,583	5,636	5,405	3,891	4,216
		Median	16,65	17,05	0	0,1	9,8	9,8	46,25	37,75	38,65	34,7	35,4	11,15	10,05	8,8	7,65
		Minimum	6,8	7,3	0	0	3,3	0,4	28	-3,3	-12,2	12,2	7	1	1,3	1,2	1,6
		Maximum	28	32,6	3,2	2,3	15,1	15,1	60,8	55,4	57,6	52,1	51,5	26,5	25,8	21,4	20,7

Table 6: Descriptive statistics of the kinematic variables of the mandible and the condyles of the adults according to facial type. Modified SPSS Table.

Report

GR	FACIAL TYPE		OP_C_RI	OP_C_LE	RET_C_RI	RET_C_LE	LAT_IN_RI	LAT_IN_LE	OP_IN	HCN_3_RI	HCN_3_LE	HCN_5_RI	HCN_5_LE	BEN_3_RI	BEN_3_LE	BEN_5_RI	BEN_5_LE
2	dolicho	Mean	15,5	16,383	6,67E-02	5,00E-02	9,55	8,15	49,033	49,967	52,8	47,683	49,45	12,183	13,933	11,617	13,167
		Std. Deviation	8,213	6,976	8,17E-02	8,37E-02	2,167	1,427	7,131	6,562	7,084	5,609	6,327	3,825	3,856	2,998	4,352
		Median	17,95	19,6	5,00E-02	0	8,65	7,85	49,7	51,9	53,2	48,45	48,7	11,8	13,8	11,3	12,45
		Minimum	4,9	7	0	0	7,9	6,8	40,7	41,8	43,2	40,9	42,1	6,3	7,9	7,5	7,2
		Maximum	23,3	22,1	0,2	0,2	13,7	10,9	57,5	58,4	61,6	55,2	57	17,9	18,7	16,8	20,2
	brachy	Mean	16,8	18,208	8,33E-02	8,33E-02	8,142	8,225	52,975	42,658	43,1	39,442	40,508	15,2	13,933	11,742	10,675
		Std. Deviation	3,24	3,071	0,175	9,37E-02	1,389	2,731	7,515	14,035	12,713	11,685	11,486	6,253	7,279	4,239	4,088
		Median	17	19	0	0,1	8,4	8,1	53,55	41,6	42	39,6	39,45	14,05	14,05	10,55	10,55
		Minimum	11,8	13,6	0	0	5,1	3,6	43,1	21,7	27,8	20,9	25,3	8,3	3,4	5,9	4,2
		Maximum	21,7	22,5	0,6	0,3	10	12,1	66,8	64	64,6	55,5	59,7	29,8	26,4	20,1	17,3
	normo	Mean	18,45	19,659	0,264	0,218	9,173	9,864	55,059	46,491	47,324	44,182	45,386	16,827	16,123	14,382	14,045
		Std. Deviation	3,627	4,85	0,432	0,289	2,803	2,535	6,145	11,418	10,154	10,491	9,568	8,173	6,265	7,436	7,121
		Median	18,15	20,8	0,1	0,1	8,6	9,35	54,75	46,1	49,1	43,05	45,5	16,2	14,9	12,85	13,05
		Minimum	13	10,9	0	0	3,2	6,3	37,9	22,2	18,5	20,4	19,9	3,6	5,6	2,5	2,9
		Maximum	26,2	26,8	1,7	1	13,9	14,1	65,1	65,1	62,1	61,3	59,3	38,5	33,3	36,4	35,9
	Total	Mean	17,512	18,732	0,18	0,153	8,92	9,115	53,53	45,863	46,867	43,285	44,532	15,643	15,138	13,175	12,903
		Std. Deviation	4,468	4,794	0,344	0,232	2,379	2,555	6,878	11,716	10,854	10,478	10,037	7,181	6,261	6,15	6,059
		Median	18,15	20	0,1	0,1	8,5	8,15	54,4	46,1	48,5	43,3	45,5	14,45	14,45	11,8	12,5
		Minimum	4,9	7	0	0	3,2	3,6	37,9	21,7	18,5	20,4	19,9	3,6	3,4	2,5	2,9
		Maximum	26,2	26,8	1,7	1	13,9	14,1	66,8	65,1	64,6	61,3	59,7	38,5	33,3	36,4	35,9

Table 7: AN0VA table of analysis of the kinematic variables of the mandible and the condyles of the children according to facial type. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni correction at 0.005 level.

ANOVA Table								
GR				Sum of Squares	df	Mean Square	F	Sig.
1	OP_C_RI * FACIAL TYPE	Between Groups	(Combined)	10,944	2	5,472	0,413	0,663
		Within Groups		1179,269	89	13,25		
		Total		1190,212	91			
	OP_C_LE * FACIAL TYPE	Between Groups	(Combined)	14,087	2	7,043	0,479	0,621
		Within Groups		1309,181	89	14,71		
		Total		1323,267	91			
	RET_C_RI * FACIAL TYPE	Between Groups	(Combined)	0,553	2	0,276	1,251	0,291
		Within Groups		19,669	89	0,221		
		Total		20,222	91			
	RET_C_LE * FACIAL TYPE	Between Groups	(Combined)	0,602	2	0,301	1,853	0,163
		Within Groups		14,467	89	0,163		
		Total		15,07	91			
	LAT_IN_RI * FACIAL TYPE	Between Groups	(Combined)	2,838	2	1,419	0,273	0,762
		Within Groups		462,767	89	5,2		
		Total		465,605	91			
	LAT_IN_LE* FACIAL TYPE	Between Groups	(Combined)	6,934	2	3,467	0,701	0,499
		Within Groups		440,115	89	4,945		
		Total		447,049	91			
	OP_IN * FACIAL TYPE	Between Groups	(Combined)	6,635	2	3,318	0,073	0,93
		Within Groups		4037,787	89	45,368		
		Total		4044,422	91			
	HCN_3_RI * FACIAL TYPE	Between Groups	(Combined)	122,938	2	61,469	0,585	0,559
		Within Groups		9353,929	89	105,1		
		Total		9476,867	91			
	HCN_3_LE * FACIAL TYPE	Between Groups	(Combined)	455,956	2	227,978	2,003	0,141
		Within Groups		10130,767	89	113,829		
		Total		10586,723	91			
	HCN_5_RI * FACIAL TYPE	Between Groups	(Combined)	54,759	2	27,38	0,413	0,663
		Within Groups		5904,701	89	66,345		
		Total		5959,46	91			
	HCN_5_LE * FACIAL TYPE	Between Groups	(Combined)	123,25	2	61,625	0,833	0,438
		Within Groups		6507,602	88	73,95		
		Total		6630,852	90			
	BEN_3_RI * FACIAL TYPE	Between Groups	(Combined)	9,013	2	4,506	0,139	0,87
		Within Groups		2881,163	89	32,373		
		Total		2890,176	91			
	BEN_3_LE * FACIAL TYPE	Between Groups	(Combined)	1,808	2	0,904	0,03	0,97
		Within Groups		2656,7	89	29,851		
		Total		2658,509	91			
	BEN_5_RI * FACIAL TYPE	Between Groups	(Combined)	6,995	2	3,498	0,227	0,797
		Within Groups		1370,836	89	15,403		
		Total		1377,831	91			
	BEN_5_LE * FACIAL TYPE	Between Groups	(Combined)	3,23	2	1,615	0,089	0,915
		Within Groups		1614,442	89	18,14		
		Total		1617,672	91			

Table 8: AN0VA table of analysis of the kinematic variables of the mandible and the condyles of the adults according to facial type. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni correction at 0.005 level.

ANOVA Table

GR				Sum of Squares	df	Mean Square	F	Sig.
2	OP_C_RI * FACIAL TYPE	Between Groups	(Combined)	49,729	2	24,864	1,262	0,295
		Within Groups		728,995	37	19,703		
		Total		778,724	39			
	OP_C_LE * FACIAL TYPE	Between Groups	(Combined)	55,297	2	27,649	1,216	0,308
		Within Groups		841,131	37	22,733		
		Total		896,428	39			
	RET_C_RI * FACIAL TYPE	Between Groups	(Combined)	0,343	2	0,172	1,483	0,24
		Within Groups		4,281	37	0,116		
		Total		4,624	39			
	RET_C_LE * FACIAL TYPE	Between Groups	(Combined)	0,215	2	0,108	2,114	0,135
		Within Groups		1,884	37	0,051		
		Total		2,1	39			
	LAT_IN_RI * FACIAL TYPE	Between Groups	(Combined)	11,056	2	5,528	0,975	0,387
		Within Groups		209,708	37	5,668		
		Total		220,764	39			
	LAT_IN_LE* FACIAL TYPE	Between Groups	(Combined)	27,423	2	13,711	2,233	0,121
		Within Groups		227,188	37	6,14		
		Total		254,611	39			
	OP_IN * FACIAL TYPE	Between Groups	(Combined)	176,455	2	88,227	1,957	0,156
		Within Groups		1668,349	37	45,091		
		Total		1844,804	39			
	HCN_3_RI * FACIAL TYPE	Between Groups	(Combined)	232,953	2	116,477	0,842	0,439
		Within Groups		5120,001	37	138,378		
		Total		5352,954	39			
	HCN_3_LE * FACIAL TYPE	Between Groups	(Combined)	385,869	2	192,934	1,698	0,197
		Within Groups		4090,758	36	113,632		
		Total		4476,627	38			
	HCN_5_RI * FACIAL TYPE	Between Groups	(Combined)	311,021	2	155,51	1,449	0,248
		Within Groups		3970,45	37	107,309		
		Total		4281,471	39			
	HCN_5_LE * FACIAL TYPE	Between Groups	(Combined)	355,458	2	177,729	1,84	0,173
		Within Groups		3573,79	37	96,589		
		Total		3929,248	39			
	BEN_3_RI * FACIAL TYPE	Between Groups	(Combined)	105,026	2	52,513	1,019	0,371
		Within Groups		1905,832	37	51,509		
		Total		2010,858	39			
	BEN_3_LE * FACIAL TYPE	Between Groups	(Combined)	47,455	2	23,728	0,593	0,558
		Within Groups		1481,339	37	40,036		
		Total		1528,794	39			
	BEN_5_RI * FACIAL TYPE	Between Groups	(Combined)	71,265	2	35,632	0,939	0,4
		Within Groups		1403,67	37	37,937		
		Total		1474,935	39			
	BEN_5_LE * FACIAL TYPE	Between Groups	(Combined)	88,699	2	44,35	1,222	0,306
		Within Groups		1343,23	37	36,304		
		Total		1431,93	39			

Opening of the right condyle

As for the children group, the mean values recorded for the right condyle were 16.12 mm for the dolichofacial group, 17.08 mm for the brachyfacial group and 16.31 mm for the normofacial group. The brachyfacial group appeared to have the greatest range of movement, since the smallest minimum and the biggest maximum value were recorded in this group. For the adult group, the mean values varied between the three subgroups. For the dolichofacial group a mean value of 15.50 mm was recorded, whereas for the brachyfacial it averaged 16.80 mm and for the normofacial group 18.45 mm. The smallest minimum value was recorded in the dolichofacial group, with 4.9 mm, and was clearly smaller than the minimum values of the other two subgroups, with 11.8 mm for the brachyfacial and 13.0 mm for the normofacial group. The greatest maximum values were fairly similar for the three subgroups. There were no significant differences between the subgroups for both groups.

Opening of the left condyle

The mean values recorded for the left condyle were 17.13 mm and 16.38 mm for the dolichofacial group, 17.83 mm and 18.21 mm for the brachyfacial group and 16.82 mm and 19.66 mm for the normofacial group, in the children and adults respectively. In the children's group, the brachyfacial group again showed the greatest range of movement. There were no significant differences between the subgroups for both groups.

Retrusion of the right condyle

For the children, the minimum value was 0.0 mm in all subgroups. Interestingly, the maximum value was only 0.6 or 0.8 mm for the dolichofacial group and the brachyfacial group respectively. In the normofacial group, though, a greater maximum retrusion of 3.2 mm was recorded. The same was observed in the adults, although the difference is smaller, with a maximum value of 1.7 mm in the normofacial group. The results were not significant between the subgroups for both groups.

Retrusion of the left condyle

The results for the left condyle are similar to those of the right condyle. For the children, the minimum value was also 0.0 mm in all subgroups. In the normofacial group of both the children and the adults a greater maximum retrusion was recorded compared to the other two subgroups. The results were not significant between the subgroups for both groups.

Laterotrusion to the right

The measurements during the lateral movements showed no significant correlation between the facial type and the maximum incisal laterotrusion for both groups. The mean measurements were 9.55 mm for the dolichofacial type, 8.14 mm for the brachyfacial type and 9.17 mm for the normofacial type in the adults and 9.34 mm, 9.86 mm and 9.65 mm in the children respectively.

Laterotrusion to the left

As for laterotrusion to the left, there were also no significant results for both children and adults. The mean values measured in the adults were 8.15 mm for the dolichofacial type, 8.23 mm for the brachyfacial type and 9.86 mm for the normofacial type. The children showed slightly higher main values for the dolichofacial and brachyfacial groups compared to the adults, namely 9.16 mm and 9.75 mm respectively.

Mouth-opening

For maximum mouth-opening capacity, the children showed a mean measurement of 47.06 mm in the dolichofacial group, 46.26 mm in the brachyfacial group, and 46.77 mm in the normofacial group. The mean measurements in the adult group were 49.03 mm for the dolichofacial group, 52.98 mm for the brachyfacial group and 55.06 mm for the normofacial group. Although a small difference exists among the groups, it is not significant. The smallest maximum mouth-opening was recorded in the brachyfacial group with 28.0 mm for the children and in the normofacial group with 37.9 mm for the adults whereas the greatest maximum mouth-opening value was recorded in the normofacial group with 60.8 mm for the children and in the brachyfacial group with 66.8 mm for the adults. The ANOVA revealed no significant difference for mouth-opening depending on the facial type, neither for the children group nor for the adult group.

HCN of the right condyle at 3 mm and at 5 mm

The results were also not significant with respect to condylar path inclination. In the children, the normofacial group showed the greatest mean inclination at 3 mm of protrusive movement with 37.30°, whereas at the protrusive path of 5 mm, the greatest mean value was calculated for the brachyfacial type with 35.05°. The mean measurements recorded for dolichofacial adult group, were greater than the mean measurements of the other two adult groups, with a mean value of 49.97° at 3 mm and 47.68° at 5 mm of protrusive movement.

HCN of the left condyle at 3 mm and at 5 mm

Similar to the right condyle, the greatest mean value at 3 mm of protrusive movement was 37.88° in the children and was recorded for the normofacial type. At 5 mm of protrusive movement in the children, the greatest mean value was also recorded for the normofacial group with 35.0°. In all subgroups, there is a clear tendency for the mean values to decrease at 5 mm of the protrusive movement. The results were not significant for the children group. For the adults the greatest value was assessed in the dolichofacial group, with 52.80° at 3 mm and 49.45° at 5 mm of protrusive movement. Although these mean values are bigger than the values of the other two subgroups, no significance was established.

Bennett angle of the right condyle at 3 mm and at 5 mm

The results concerning the Bennett angle of the right condyle were also not significant for the both groups and for both measurements at 3 mm and at 5 mm of laterotrusion. A reduction of the mean value of the Bennett angle was observed at the first 5 mm of movement in comparison to the first 3mm in both groups.

Bennett angle of the left condyle at 3 mm and at 5 mm

The results regarding the left Bennett angle were similar to those of the right side. The reduction of the mean value of the condylar path inclination at the first 5 mm of movement in comparison to the first 3 mm in both groups was observed, too. No significant correlation between the left Bennett angle and the facial type was observed either for the children or for the adults.

6.3. Body weight

Opening of the right condyle

The results were only significant for the children’s group. A weak positive correlation between weight and opening of the right condyle was observed. After Bonferroni’s correction, there were no significant results. For the adults, the correlation was negative and weak, but insignificant.

Table 9: Spearman's rank correlation (rho) between right condyle opening and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,221	0,101	2,152	,034(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,233	0,1	2,273	,025(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,032	0,151	-0,199	,843(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,017	0,172	-0,105	,917(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Opening of the left condyle

For the left side, results were insignificant in both groups.

Table 10: Spearman's rank correlation (rho) between left condyle opening and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,234	0,104	2,282	,025(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,204	0,101	1,975	,051(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,009	0,146	-0,056	,956(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,003	0,168	-0,018	,986(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Retrusion of the right condyle

The retrusion was not related significantly to weight for any of the groups. The correlation was weakly positive for both groups.

Table 11: Spearman's rank correlation (rho) between right condyle retrusion and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,119	0,11	-1,136	,259(c)
	Ordinal by Ordinal	Spearman Correlation	0,042	0,111	0,395	,694(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	0,089	0,082	0,549	,586(c)
	Ordinal by Ordinal	Spearman Correlation	0,187	0,151	1,173	,248(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Retrusion of the left condyle

The results for the left condyle, like in the right side, were not significant.

Table 12: Spearman's rank correlation (rho) between left condyle retrusion and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,124	0,098	-1,19	,237(c)
	Ordinal by Ordinal	Spearman Correlation	0,049	0,109	0,466	,642(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	0,012	0,1	0,073	,942(c)
	Ordinal by Ordinal	Spearman Correlation	0,038	0,15	0,231	,818(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Laterotrusion to the right

Regarding laterotrusion to the right, there were also no significant results for any of the groups. The correlation was weakly negative for both groups.

Table 13: Spearman's rank correlation (rho) between laterotrusion to the right and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	-0,119	0,107	-1,139	,258(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,055	0,109	-0,527	,600(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	0	0,165	0,002	,998(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,032	0,168	-0,197	,845(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Laterotrusion to the left

Similar to the right side, the results for laterotrusion to the left were not significant. The correlation between weight and laterotrusion to the left was weakly positive for the children group and negative for the adults.

Table 14: Spearman's rank correlation (rho) laterotrusion to the left and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,002	0,103	0,022	,983(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,085	0,102	0,809	,420(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,297	0,135	-1,915	,063(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,27	0,155	-1,731	,092(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Mouth-opening

The results regarding maximum mouth-opening capacity and weight were insignificant. The correlation between weight and the maximum mouth-opening capacity of the children was weakly positive and weakly negative for the adults.

Table 15: Spearman's rank correlation (rho) between mouth opening and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,008	0,092	0,076	,940(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,007	0,104	0,071	,944(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,015	0,181	-0,093	,926(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,015	0,186	-0,095	,925(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

HCN of the right condyle at 3 mm and at 5 mm

The condylar path inclination was significantly related to weight only for the adults at the 3 mm and 5 mm of protrusive movement. The correlation was negative. The correlation in the children was weakly positive, but insignificant, either at the 3 mm of protrusive movement or at the first 5 mm of protrusive movement.

Table 16: Spearman's rank correlation (rho) between HCN of the right condyle at 3 mm and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,074	0,092	0,706	,482(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,046	0,1	0,433	,666(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,405	0,115	-2,732	,010(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,392	0,138	-2,626	,012(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 17: Spearman's rank correlation (rho) between HCN of the right condyle at 5 mm and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,089	0,095	0,85	,398(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,076	0,099	0,723	,471(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,388	0,101	-2,592	,013(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,413	0,127	-2,794	,008(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

HCN of the left condyle at 3 mm and at 5 mm

There was no significant relationship between weight and the condylar path inclination angle at 3 mm and at 5 mm of protrusive movement for any of the groups. The correlation was negative for both groups.

Table 18: Spearman's rank correlation (rho) between HCN of the left condyle at 3 mm and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	-0,002	0,092	-0,017	,987(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,009	0,102	-0,087	,931(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,218	0,125	-1,361	,182(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,205	0,144	-1,273	,211(c)
	N of Valid Cases		39			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 19: Spearman's rank correlation (rho) between HCN of the left condyle at 3 mm and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	-0,009	0,093	-0,086	,932(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,023	0,102	-0,214	,831(c)
	N of Valid Cases		91			
2	**Interval by Interval**	**Pearson's R**	-0,241	0,12	-1,53	,134(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,237	0,148	-1,504	,141(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Bennett angle of the right condyle at 3 mm and at 5 mm

The Bennett angle of the right condyle was significant negatively related to weight only for the adults at 3 mm of laterotrusion, whereas at 5 mm of laterotrusion the relation was insignificant. The correlation in the children was weak and negative, either at the 3 mm of protrusive movement or at the first 5 mm of protrusive movement. When Bonferroni's correction was used, no significant results were found.

Table 20: Spearman's rank correlation (rho) between Bennett angle of the right condyle at 3 mm and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	-0,01	0,11	-0,099	,921(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,013	0,11	-0,122	,903(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,413	0,095	-2,795	,008(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,385	0,141	-2,575	,014(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 21: Spearman's rank correlation (rho) between Bennett angle of the right condyle at 5 mm and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	-0,116	0,11	-1,109	,271(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,132	0,103	-1,262	,210(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,314	0,116	-2,037	,049(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,285	0,168	-1,831	,075(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Bennett angle of the left condyle at 3 mm and at 5 mm

Contrary to the right side, the left Bennett angle was not related significantly to weight, neither for the adults nor for the children. The relationship was weakly negative for all subgroups at 3 mm and 5 mm of laterotrusion. As an exception, the Bennett angle estimated at the first 5 mm of laterotrusion in the children showed a weakly positive association with weight.

Table 22: Spearman's rank correlation (rho) between Bennett angle of the left condyle at 3 mm and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures

GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,104	0,089	-0,988	,326(c)
	Ordinal by Ordinal	Spearman Correlation	-0,05	0,107	-0,475	,636(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	-0,24	0,168	-1,527	,135(c)
	Ordinal by Ordinal	Spearman Correlation	-0,303	0,171	-1,963	,057(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 23 Spearman's rank correlation (rho) between Bennett angle of the left condyle at 5 mm and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures

GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,05	0,089	-0,478	,634(c)
	Ordinal by Ordinal	Spearman Correlation	0,01	0,105	0,093	,926(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	-0,285	0,135	-1,835	,074(c)
	Ordinal by Ordinal	Spearman Correlation	-0,279	0,17	-1,793	,081(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

6.4. Body height

<u>Opening of the right condyle</u>

Results were not significant for the both groups. A weak positive relationship between body height and opening of the right condyle was observed in the children, and a weak negative association in the adults.

Table 24: Spearman's rank correlation (rho) between right condyle opening and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,121	0,103	1,155	,251(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,1	0,101	0,957	,341(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,39	0,227	-2,614	,013(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,117	0,184	-0,725	,473(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

<u>Opening of the left condyle</u>

For the left side the results were similar to the right side.

Table 25: Spearman's rank correlation (rho) between left condyle opening and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,174	0,107	1,676	,097(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,106	0,098	1,007	,316(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,425	0,184	-2,892	,006(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,248	0,178	-1,577	,123(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Retrusion of the right condyle

The retrusion was not related significantly to height for the children group. The correlation was negative. However the results showed a strong positive significant correlation between the retrusion of the right condyle and height in the adults.

Table 26: Spearman's rank correlation (rho) between right condyle retrusion and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,137	0,173	-1,312	,193(c)
	Ordinal by Ordinal	Spearman Correlation	-0,031	0,108	-0,292	,771(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	0,378	0,112	2,517	,016(c)
	Ordinal by Ordinal	Spearman Correlation	0,549	0,116	4,047	,000(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Retrusion of the left condyle

The results for the left condyle were similar to those of the right side. A significant correlation was also observed only in the adult group.

Table 27: Spearman's rank correlation (rho) between left condyle retrusion and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,165	0,128	-1,585	,116(c)
	Ordinal by Ordinal	Spearman Correlation	-0,072	0,102	-0,687	,494(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	0,375	0,105	2,493	,017(c)
	Ordinal by Ordinal	Spearman Correlation	0,458	0,126	3,179	,003(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Laterotrusion to the right

For laterotrusion to the right, there were no significant results for any of the groups. The correlation was weakly negative for the children and weakly positive for the adults.

Table 28: Spearman's rank correlation (rho) between laterotrusion to the right and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	-0,104	0,106	-0,996	,322(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,095	0,106	-0,906	,367(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	0,141	0,098	0,877	,386(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,07	0,141	0,431	,669(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Laterotrusion to the left

Similar to the right side, the results for laterotrusion to the left were not significant. The correlation was positive for both groups.

Table 29: Spearman's rank correlation (rho) laterotrusion to the left and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,125	0,107	1,193	,236(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,11	0,103	1,049	,297(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	0,075	0,109	0,466	,644(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,12	0,13	0,746	,460(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Mouth-opening

The results for maximum mouth-opening capacity and body height were insignificant. The correlation was weakly positive for the children and weakly negative for the adults.

Table 30: Spearman's rank correlation (rho) between mouth opening and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,053	0,094	0,502	,617(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,008	0,101	0,072	,943(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	-0,233	0,189	-1,479	,147(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,111	0,166	-0,69	,495(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

HCN of the right condyle at 3 mm and at 5 mm

The condylar path inclination was positively related to body height only for the children at the first 5 mm of protrusive movement. After Bonferroni's correction the results were not significant.

Table 31: Spearman's rank correlation (rho) between HCN of the right condyle at 3 mm and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,182	0,08	1,758	,082(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,179	0,092	1,731	,087(c)
	N of Valid Cases		92			
2	**Interval by Interval**	**Pearson's R**	0,184	0,121	1,151	,257(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,113	0,157	0,699	,489(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 32: Spearman's rank correlation (rho) between HCN of the right condyle at 5 mm and body weight. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,226	0,085	2,202	,030(c)
	Ordinal by Ordinal	Spearman Correlation	0,251	0,092	2,463	,016(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	0,211	0,112	1,328	,192(c)
	Ordinal by Ordinal	Spearman Correlation	0,103	0,152	0,637	,528(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

HCN of the left condyle at 3 mm and at 5 mm

Similar to the right side, the results were positive for the children at the first 5 mm of protrusive movement, but not after Bonferroni's correction.

Table 33: Spearman's rank correlation (rho) between HCN of the left condyle at 3 mm and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,158	0,083	1,522	,131(c)
	Ordinal by Ordinal	Spearman Correlation	0,173	0,095	1,666	,099(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	0,313	0,123	2,006	,052(c)
	Ordinal by Ordinal	Spearman Correlation	0,27	0,154	1,707	,096(c)
	N of Valid Cases		39			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 34: Spearman's rank correlation (rho) between HCN of the left condyle at 5 mm and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,207	0,082	1,998	,049(c)
	Ordinal by Ordinal	Spearman Correlation	0,207	0,093	2,001	,048(c)
	N of Valid Cases		91			
2	Interval by Interval	Pearson's R	0,303	0,114	1,957	,058(c)
	Ordinal by Ordinal	Spearman Correlation	0,226	0,153	1,431	,160(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Bennett angle of the right condyle at 3 mm and at 5 mm

The Bennett angle of the right condyle was positively, but insignificantly related to the height for the children at the 3 mm of laterotrusion, whereas at the 5 mm of laterotrusion the relationship was negative, but insignificant. For the adults the results were negative and insignificant at the 3 mm of laterotrusion and positive and insignificant at the first 5 mm of protrusive movement.

Table 35: Spearman's rank correlation (rho) between Bennett angle of the right condyle at 3 mm and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,03	0,109	0,284	,777(c)
	Ordinal by Ordinal	Spearman Correlation	0,033	0,107	0,314	,754(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	-0,097	0,104	-0,603	,550(c)
	Ordinal by Ordinal	Spearman Correlation	-0,059	0,159	-0,367	,715(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 36: Spearman's rank correlation (rho) between Bennett angle of the right condyle at 5 mm and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,112	0,097	-1,07	,287(c)
	Ordinal by Ordinal	Spearman Correlation	-0,119	0,103	-1,138	,258(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	-0,012	0,112	-0,071	,944(c)
	Ordinal by Ordinal	Spearman Correlation	0,023	0,168	0,144	,887(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Bennett angle of the left condyle at 3 mm and at 5 mm

The Bennett angle of the left condyle was not related significantly to height, neither for the adults nor for the children. The relationship was weakly negative for the children at 3 mm and 5 mm of laterotrusion. For the adults, it was weakly positive for both measurements.

Table 37: Spearman's rank correlation (rho) between Bennett angle of the left condyle at 3 mm and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,069	0,097	-0,657	,513(c)
	Ordinal by Ordinal	Spearman Correlation	-0,048	0,107	-0,453	,652(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	0,101	0,131	0,627	,535(c)
	Ordinal by Ordinal	Spearman Correlation	0,065	0,161	0,401	,691(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 38: Spearman's rank correlation (rho) between Bennett angle of the left condyle at 5 mm and body height. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,04	0,1	-0,375	,708(c)
	Ordinal by Ordinal	Spearman Correlation	-0,017	0,108	-0,164	,870(c)
	N of Valid Cases		92			
2	Interval by Interval	Pearson's R	0,133	0,146	0,827	,413(c)
	Ordinal by Ordinal	Spearman Correlation	0,152	0,164	0,949	,348(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

6.5. Overjet

Opening of the right condyle

The results were not significant for the both groups. A weak positive relationship between the overjet and opening of the right condyle was observed in the children and a weak negative correlation in the adults.

Table 39: Spearman's rank correlation (rho) between right condyle opening and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,179	0,086	1,7	,093(c)
	Ordinal by Ordinal	Spearman Correlation	0,152	0,103	1,432	,156(c)
	N of Valid Cases		89			
2	Interval by Interval	Pearson's R	0,061	0,115	0,377	,709(c)
	Ordinal by Ordinal	Spearman Correlation	-0,169	0,164	-1,056	,297(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Opening of the left condyle

The results were similar to the right side.

Table 40: Spearman's rank correlation (rho) between left condyle opening and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,156	0,081	1,473	,144(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,109	0,105	1,02	,311(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	0,09	0,097	0,554	,583(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,031	0,152	-0,192	,848(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Retrusion of the right condyle

The retrusion was not significantly related to the overjet for both groups.

Table 41: Spearman's rank correlation (rho) between right condyle retrusion and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,119	0,104	1,115	,268(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,097	0,113	0,907	,367(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	-0,096	0,083	-0,592	,558(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,11	0,154	0,682	,500(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Retrusion of the left condyle

The results for the left condyle were similar to those of the right side.

Table 42: Spearman's rank correlation (rho) between left condyle retrusion and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,041	0,109	0,382	,703(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,066	0,105	0,616	,539(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	-0,075	0,104	-0,463	,646(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,155	0,166	0,969	,339(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Laterotrusion to the right

As for laterotrusion to the right there were no significant results for any of the groups. The correlation was weakly positive for both groups.

Table 43: Spearman's rank correlation (rho) between laterotrusion to the right and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,031	0,093	0,287	,775(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,008	0,113	0,073	,942(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	0,313	0,169	2,033	,049(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,154	0,173	0,961	,343(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Laterotrusion to the left

The results were similar to the right side.

Table 44: Spearman's rank correlation (rho) between laterotrusion to the left and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,022	0,108	0,208	,836(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,101	0,111	0,949	,345(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	0,39	0,153	2,615	,013(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,25	0,166	1,591	,120(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Mouth-opening

The results regarding maximum mouth-opening capacity and the overjet were insignificant. The correlation was weakly positive for the children and weakly negative for the adults.

Table 45: Spearman's rank correlation (rho) between mouth opening and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,028	0,079	0,263	,793(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,015	0,101	0,145	,885(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	-0,315	0,168	-2,047	,048(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,249	0,161	-1,588	,121(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

HCN of the right condyle at 3 mm and at 5 mm

The condylar path inclination was positively related to the overjet only for the children at the first 3 mm of protrusive movement. In the same group the correlation was positive, but insignificant at the 5 mm of protrusive movement. In the adults the results were negatively associated with the overjet. After the Bonferroni correction results were insignificant.

Table 46: Spearman's rank correlation (rho) between HCN of the right condyle at 3 mm and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,183	0,104	1,736	,086(c)
	Ordinal by Ordinal	Spearman Correlation	0,225	0,108	2,15	,034(c)
	N of Valid Cases		89			
2	Interval by Interval	Pearson's R	-0,055	0,101	-0,343	,734(c)
	Ordinal by Ordinal	Spearman Correlation	-0,077	0,15	-0,473	,639(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 47: Spearman's rank correlation (rho) between HCN of the right condyle at 5 mm and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,15	0,11	1,42	,159(c)
	Ordinal by Ordinal	Spearman Correlation	0,183	0,107	1,739	,086(c)
	N of Valid Cases		89			
2	Interval by Interval	Pearson's R	-0,062	0,095	-0,384	,703(c)
	Ordinal by Ordinal	Spearman Correlation	-0,094	0,145	-0,58	,565(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						

HCN of the left condyle at 3 mm and at 5 mm

Contrary to the right side the results were not significant.

Table 48: Spearman's rank correlation (rho) between HCN of the left condyle at 3 mm and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,152	0,094	1,431	,156(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,169	0,107	1,604	,112(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	-0,143	0,08	-0,878	,386(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,155	0,14	-0,954	,346(c)
	N of Valid Cases		39			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 49: Spearman's rank correlation (rho) between HCN of the left condyle at 5 mm and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,138	0,097	1,294	,199(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,173	0,108	1,626	,108(c)
	N of Valid Cases		88			
2	**Interval by Interval**	**Pearson's R**	-0,136	0,075	-0,847	,402(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,156	0,138	-0,972	,337(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Bennett angle of the right condyle at 3 mm and at 5 mm

The Bennett angle of the right condyle showed an insignificant positive correlation with the overjet for the children at the 3 mm and 5 mm of laterotrusion, whereas for the adults the results were negative without significance.

Table 50: Spearman's rank correlation (rho) between Bennett angle of the right condyle at 3 mm and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,13	0,086	1,227	,223(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,201	0,108	1,918	,058(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	-0,067	0,097	-0,411	,683(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,056	0,162	-0,348	,730(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 51: Spearman's rank correlation (rho) between Bennett angle of the right condyle at 3 mm and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,054	0,111	0,503	,616(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,171	0,114	1,623	,108(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	-0,141	0,091	-0,876	,386(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,156	0,167	-0,971	,338(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Bennett angle of the left condyle at 3mm and at 5mm

The results were similar to the right side.

Table 52: Spearman's rank correlation (rho) between Bennett angle of the left condyle at 3 mm and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,003	0,109	0,028	,978(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,09	0,106	0,846	,400(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	-0,151	0,116	-0,943	,351(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,087	0,167	-0,537	,595(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 53: Spearman's rank correlation (rho) between Bennett angle of the left condyle at 5 mm and overjet. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	-0,033	0,111	-0,305	,761(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,029	0,113	0,268	,790(c)
	N of Valid Cases		89			
2	**Interval by Interval**	**Pearson's R**	-0,173	0,104	-1,081	,286(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,162	0,168	-1,014	,317(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

6.6. Overbite

Opening of the right condyle

The results were not significant for the both groups. A weak positive relationship between the overbite and opening of the right condyle was observed in the children and a weak negative relation in the adults.

Table 54: Spearman's rank correlation (rho) between right condyle opening and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,104	0,09	0,986	,327(c)
	Ordinal by Ordinal	Spearman Correlation	0,067	0,105	0,634	,528(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	-0,266	0,115	-1,699	,097(c)
	Ordinal by Ordinal	Spearman Correlation	-0,216	0,159	-1,364	,181(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Opening of the left condyle

The results were similar to the right side.

Table 55: Spearman's rank correlation (rho) between left condyle opening and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,148	0,083	1,408	,163(c)
	Ordinal by Ordinal	Spearman Correlation	0,097	0,102	0,912	,364(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	-0,201	0,095	-1,264	,214(c)
	Ordinal by Ordinal	Spearman Correlation	-0,116	0,153	-0,721	,475(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Retrusion of the right condyle

The retrusion was not related significantly to the overjet for both groups.

Table 56: Spearman's rank correlation (rho) between right condyle retrusion and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,117	0,121	-1,108	,271(c)
	Ordinal by Ordinal	Spearman Correlation	-0,037	0,109	-0,343	,732(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	0,119	0,115	0,736	,466(c)
	Ordinal by Ordinal	Spearman Correlation	-0,061	0,17	-0,379	,707(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Retrusion of the left condyle

For the adults the correlation was positive. There were no significant results after Bonferroni's correction. For the children, a weak positive, but insignificant relationship between the overbite and retrusion of the left condyle was established.

Table 57: Spearman's rank correlation (rho) between left condyle retrusion and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	-0,032	0,119	-0,302	,763(c)
	Ordinal by Ordinal	Spearman Correlation	0,129	0,104	1,219	,226(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	0,317	0,095	2,063	,046(c)
	Ordinal by Ordinal	Spearman Correlation	0,385	0,154	2,574	,014(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Laterotrusion to the right

As for laterotrusion to the right there were no significant results for any of the groups. The correlation was positive for both groups.

Table 58: Spearman's rank correlation (rho) between laterotrusion to the right and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,081	0,124	0,76	,449(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,131	0,109	1,235	,220(c)
	N of Valid Cases		90			
2	**Interval by Interval**	**Pearson's R**	0,195	0,137	1,225	,228(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,278	0,146	1,781	,083(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Laterotrusion to the left

Correlation with the left condyle was positive for the adult group. After Bonferroni's correction, results were not significant. For the children a weakly positive, but in-significant relationship between the overbite and laterotrusion to the left was established.

Table 59: Spearman's rank correlation (rho) between laterotrusion to the left and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,011	0,12	0,105	,917(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,029	0,113	0,272	,786(c)
	N of Valid Cases		90			
2	**Interval by Interval**	**Pearson's R**	0,431	0,127	2,943	,006(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,343	0,152	2,254	,030(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Mouth-opening

The results for maximum mouth-opening capacity and the overbite were not significant. The correlation was weak, positive for the children and negative for the adults.

Table 60: Spearman's rank correlation (rho) between mouth opening and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,035	0,101	0,327	,744(c)
	Ordinal by Ordinal	Spearman Correlation	0,021	0,105	0,192	,848(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	-0,183	0,136	-1,145	,259(c)
	Ordinal by Ordinal	Spearman Correlation	-0,081	0,159	-0,502	,619(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

HCN of the right condyle at 3 mm and at 5 mm

The correlation was positive, but insignificant for the children group. In the adults the results were negatively, but insignificantly associated with the overbite.

Table 61: Spearman's rank correlation (rho) between HCN of the right condyle at 3 mm and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,16	0,097	1,52	,132(c)
	Ordinal by Ordinal	Spearman Correlation	0,185	0,104	1,767	,081(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	-0,012	0,191	-0,076	,940(c)
	Ordinal by Ordinal	Spearman Correlation	-0,028	0,179	-0,175	,862(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 62: Spearman's rank correlation (rho) between HCN of the right condyle at 5 mm and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,177	0,102	1,69	,094(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,191	0,103	1,827	,071(c)
	N of Valid Cases		90			
2	**Interval by Interval**	**Pearson's R**	-0,034	0,199	-0,208	,837(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,053	0,178	-0,328	,745(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

HCN of the left condyle at 3 mm and at 5 mm

The results are similar to those of the right side.

Table 63: Spearman's rank correlation (rho) between HCN of the left condyle at 3 mm and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			**Value**	**Asymp. Std. Error(a)**	**Approx. T(b)**	**Approx. Sig.**
1	**Interval by Interval**	**Pearson's R**	0,102	0,094	0,961	,339(c)
	Ordinal by Ordinal	**Spearman Correlation**	0,144	0,103	1,367	,175(c)
	N of Valid Cases		90			
2	**Interval by Interval**	**Pearson's R**	-0,179	0,198	-1,106	,276(c)
	Ordinal by Ordinal	**Spearman Correlation**	-0,204	0,18	-1,265	,214(c)
	N of Valid Cases		39			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 64: Spearman's rank correlation (rho) between HCN of the right condyle at 5 mm and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005 level.

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,144	0,099	1,357	,178(c)
	Ordinal by Ordinal	Spearman Correlation	0,179	0,105	1,698	,093(c)
	N of Valid Cases		89			
2	Interval by Interval	Pearson's R	-0,164	0,2	-1,027	,311(c)
	Ordinal by Ordinal	Spearman Correlation	-0,211	0,179	-1,33	,191(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Bennett angle of the right condyle at 3 mm and at 5 mm

The Bennett angle of the right condyle was insignificantly positively related to the overbite for the both groups.

Table 65: Spearman's rank correlation (rho) between Bennett angle of the right condyle at 3 mm and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,085	0,096	0,8	,426(c)
	Ordinal by Ordinal	Spearman Correlation	0,08	0,104	0,752	,454(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	0,267	0,138	1,706	,096(c)
	Ordinal by Ordinal	Spearman Correlation	0,179	0,152	1,121	,269(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 66: Spearman's rank correlation (rho) between Bennett angle of the right condyle at 5 mm and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,044	0,102	0,41	,683(c)
	Ordinal by Ordinal	Spearman Correlation	0,039	0,111	0,365	,716(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	0,128	0,104	0,797	,430(c)
	Ordinal by Ordinal	Spearman Correlation	0,137	0,16	0,852	,400(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Bennett angle of the left condyle at 3 mm and at 5 mm

The correlation was positive for the children group at the 3 mm of laterotrusion. After using the Bonferroni correction the results were not significant. For the adults a weakly positive, non-significant relation between the overbite and the Bennett angle was established.

Table 67: Spearman's rank correlation (rho) between Bennett angle of the leftt condyle at 3 mm and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,214	0,104	2,06	,042(c)
	Ordinal by Ordinal	Spearman Correlation	0,216	0,109	2,072	,041(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	0,171	0,126	1,071	,291(c)
	Ordinal by Ordinal	Spearman Correlation	0,108	0,156	0,671	,506(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

Table 68: Spearman's rank correlation (rho) between Bennett angle of the left condyle at 5 mm and overbite. Modified SPSS Table. Significant (unadjusted) at 0.05 level, after Bonferroni Correction at 0.005

Symmetric Measures						
GR			Value	Asymp. Std. Error(a)	Approx. T(b)	Approx. Sig.
1	Interval by Interval	Pearson's R	0,143	0,107	1,355	,179(c)
	Ordinal by Ordinal	Spearman Correlation	0,117	0,112	1,103	,273(c)
	N of Valid Cases		90			
2	Interval by Interval	Pearson's R	0,096	0,091	0,594	,556(c)
	Ordinal by Ordinal	Spearman Correlation	0,165	0,153	1,03	,310(c)
	N of Valid Cases		40			
a Not assuming the null hypothesis.						
b Using the asymptotic standard error assuming the null hypothesis.						
c Based on normal approximation.						

6.7. Right versus left side

The paired t-test in the children showed significant differences between the right and the left side only for condylar path length.

Table 69: Paired t-test between the right and the left side for the different kinematic variables in the children. Modified SPSS table.

Paired Samples Test									
GR=1		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval				
					Lower	Upper			
Pair 1	OP_C_RI - OP_C_LE	-0,68	1,541	0,161	-1	-0,361	-4,234	91	0
Pair 2	RET_C_RI - RET_C_LE	-2,83E-02	0,271	2,83E-02	-8,44E-02	2,79E-02	-1	91	0,32
Pair 3	LAT_IN_RI LAT_IN_LE								
Pair 4	HCN_3_RI - HCN_3_LE	0,336	5,51	0,574	-0,805	1,477	0,585	91	0,56
Pair 1	HCN_5_RI - HCN_5_LE	0,224	4,13	0,433	-0,636	1,084	0,518	90	0,606
Pair 2	BEN_3_RI - BEN_3_LE	0,772	6,212	0,648	-0,515	2,058	1,192	91	0,237
Pair 3	BEN_5_RI - BEN_5_LE	0,762	3,782	0,394	-2,13E-02	1,545	1,932	91	0,056

Table 70: : Paired t-test between the right and the left side for the different kinematic variables in the adults. Modified SPSS table.

Paired Samples Test									
GR=2		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval				
					Lower	Upper			
Pair 1	OP_C_RI - OP_C_LE	-1,22	2,149	0,34	-1,907	-0,533	-3,591	39	0,001
Pair 2	RET_C_RI - RET_C_LE	2,75E-02	0,206	3,26E-02	-3,85E-02	9,35E-02	0,843	39	0,404
Pair 3	LAT_IN_RI LAT_IN_LE								
Pair 4	HCN_3_RI - HCN_3_LE	-0,754	5,623	0,9	-2,576	1,069	-0,837	38	0,408
Pair 5	HCN_5_RI - HCN_5_LE	-1,248	4,617	0,73	-2,724	0,229	-1,709	39	0,095
Pair 6	BEN_3_RI - BEN_3_LE	0,505	3,543	0,56	-0,628	1,638	0,901	39	0,373
Pair 7	BEN_5_RI - BEN_5_LE	0,273	1,987	0,314	-0,363	0,908	0,867	39	0,391

Also in the adults, significant differences between the right and the left side were shown only for the condylar path length.

7. Discussion

7.1. Methods

Our study involved both a clinical examination and an instrumental one. The clinical examination of the stomatognathic system comprised observation and palpation. Parameters such as pain or sensibility upon palpation, pain or sensibility during mandibular movement as well as TMJ appearance, deformation, mobility and sound were clinically assessed. During the clinical examination the following aspects were examined: age, gender, body weight and height, habitual occlusion, mouth breathing, facial type, overjet, overbite, gnashing of the teeth and pain on TMJ. The subjects should be free of symptoms of temporomandibular disorders, should not be orthodontically treated and especially the adults should not have extended dental restorations.

The instrumental part was carried out with the JMA System of Analysis. This system enables recording of the mandibular movements, namely of the condyles and the incisal point. It has already been used by other authors [Reicheneder 2008, 2009, Baqaien 2006, 2007, 2009] in order to examine the function of the stomatognathic system. The reliability of the device has already been tested by Wessling 2003 and Verch 2002. In his study Wessling compared two recording systems the GAMMA-CADIAX® and the ZEBRIS-JMA®. He found that the horizontal condylar path inclination angle (CPIA) can be measured reproducibly with both recording systems, but slightly more so with the Cadiax, whereas the Bennett angle was more reproducible using the JMA®. Another result of his study was that the HCN is more reproducible than the Bennett angle. Although the JMA® is a newer measuring system compared to the CADIAX® system, the recordings achieved with this device were highly reproducible. Due to the low weight and the easy installation of the JMA®, it is very well accepted by the patients. In addition the results from Verch 2002 were also positive for the JMA device. He compared three registration systems.

These were the Cadiax III system, the Condylograph and Jaw Motion Analysis system. They all showed good to very good reproducibility. Like Wessling he found that HCN is more reproducible in comparison to the Bennett angle. Moreover, the reproducibility of the Bennett angle was higher for the JMA system.

Since high reproducibility of movements was also important for the present study every movement was demonstrated to the subjects and then repeated several times before being recorded. Subsequently, every subject was asked to carry out the movement twice. The mean value was then estimated from the two recordings.

Maximum intercuspation was chosen to be the beginning and ending position of every movement, since this position is highly repeatable and could be occupied without manipulation, especially by the children. The subjects were asked to carry out every movement toothguided. Even though this was sometimes difficult for the children, most of them managed to do it after two or three unsuccessful attempts.

A defined reference plane was also necessary for this study. We used the arbitrary axis-orbital plane as our reference plane, which is considered suitable by the manufactures. The arbitrary axis was defined through the ear tragus superior points of the right and left side. We chose the arbitrary method which has been widely used because it is fairly simple and fast [Teteruck 1966, Bernhardt 2003]. In addition the study of Bernhardt et al. 2003 suggests that the arbitrarily determined reference points are reliable to use. Baqaien 2006 observed that in many children the tracing paths of the protrusion and opening movements did not coincide, which is necessary for the definition of the kinematic center. He also suggests that the arbitrary method is more suitable for children who may not have the ability to perform the smooth coordinated protrusive and opening movements required for the definition of the kinematic center. On the other hand, according to Ćatić et al. 1999 the hinge axis is more adequate for reconstruction of mandibular movements in the articulator. For these reasons we consider our choice to be reasonable.

The subjects were asked to sit in an upright and relaxed position, looking straight ahead, without moving. This was somewhat difficult for some children. Although they were asked to be concentrated and quiet, this was not always possible due to their young age. In fact, changes of the head position could lead to false results, but as the sending and receiver sensors remained stable on the subjects we assume that these small movements did not affect results.

The bite fork was fastened on the labial surface of the front mandibular teeth. There should be no composite interfering in maximum intercuspation, in order not to affect the function of the mandible. In some cases the bite fork was loosened before the analysis was completed. In these cases the whole procedure was repeated from the beginning, in order to avoid minimal displacement of the bite fork which would also lead to false results.

Statistical analysis of the recording results was carried out using the SPSS software program with the assistance of an expert in biostatistics.

7.2. Results

7.2.1 Comparison with literature

The kinematic variables of the mandible and the condyles have always been a subject of discussion, hence many investigations are available. Studying the movements of the mandible, the maximum mouth-opening, the laterotrusions and the condylar path inclination angle were of special interest to the authors. Especially the maximum mouth-opening capacity and the maximum laterotrusions of the mandible are most reliably measurable, as they represent more objective parameters. It is important to record the maximum mouth-opening capacity, because it is regarded as an important parameter in order to evaluate the function of the mandible. The principles of biomechanics of TMJ function are supposed to be the same in all human beings [Steinhardt 1959, Lindblom 1960]. The *maximum mouth-opening capacity* is suggested to be used as a diagnostic index of normal function or dysfunction of the mandible by Sheppard and Sheppard 1965 whereas according to Rosenbaum 1975 it does not correlate significantly with other TMJ dysfunction symptoms. Travers et al. 2000 suggest that the maximum incisal mouth-opening does not provide any reliable information about condylar translation and, therefore, should not be used as a diagnostic indicator of condylar movement. In the study of Clark 1986 the maximum mouth-opening capacity was found to be significantly smaller in subjects with TMJ dysfunction. With respect to maximum mouth-opening capacity, there is a wide range of values that are considered to be normal. Posselt 1952 described as normal an average maximum opening of 43.4 mm. Travell 1960 found that the average maximum opening value was 59 mm (range 50 to 73 mm) in men with an average age of 21.7 years, and 53 mm (range 45 to 65 mm) in women with an average age of 19.6 years. He concluded that the average normal maximum opening should not be less than 50 mm for men and 45 mm for women. The results of Rosenbaum 1975 were similar, with an average maximum opening of 44.9 mm in the adults. Rieder 1978 found that the mean maximum mouth-opening was between 40-60 mm in men and 35-55 mm in women.

Ingervall 1970 studied the range of movement of the mandible in a large sample of children and young women. He examined 103 7-year-old children, 110 10-year-old children and 60 adult women aged 20 years. The mean maximum mouth-opening was 46 mm for the 7-year-olds, 51 mm for the 10-year-olds and 51 mm for the adult women.

In our study the maximal mouth-opening capacity was measured as the linear distance of the incisal points. The mean values were 53.53 mm for the adult group, actually 52.15 mm for the men and 54.9 mm for the women. The children group showed a more limited range of motion with a mean value of 46.73 mm, namely 47.72 mm for the boys and 45.65 mm for the girls. The minimum opening movement was 37.9 mm for the adults and 28.0 mm for the children, while the maximum opening movement was 66.8 mm for the adults and 60.8mm for the children. Our mean values are similar to those of Ingervall.

Rothenberg et al. 1991 examined a group of 189 Caucasian children (mean age 10 years) and found a mean maximum mouth capacity of 43.9 mm. The minimum value recorded was 32 mm and the maximum 64 mm.

Travers et al. 2000 recorded the mandibular movements of a sample of 27 adult females with an optoelectric jaw-tracking system (Optotrak). He found that the maximum mouth-opening had a mean value of 46.6 mm. Yoon et al. 2006 found that the maximum mouth-opening ranges between 34.9 and 54.3 mm. As for the maximum value, the findings of Yoon are smaller than ours. However, since the sample of Yoon was very small, his results may not be reliable.

In comparison to the findings of Reicheneder et al. 2008, the current mean maximum opening capacity in children was quite similar. According to their findings the mean maximum opening capacity in children varied from 48.7 mm to 56.3 mm for the different age-groups examined. The minimum opening movement was 39 mm and the maximum was 61.7 mm in the children group. Our findings are similar for the maximum values, but the minimum value in our children group was slightly smaller with 28.0 mm. In our study the adults also had a more limited minimum mouth-opening capacity of 37.9 mm compared to 50.3 mm. The maximum opening capacity of the adults was similar in the two studies (69.8 mm in the study of Reicheneder and 66.8 mm in our study).

Baqaien 2006 found that the mean mouth-opening capacity in children of about the same age with our subjects varies between 43.6 mm and 47.2 mm. In this study the minimum opening capacity was 34.5 mm and the maximum was 61.5 mm. Our findings support the findings of Baqaien. In the adults he recorded a mean value of 50.4 mm with a minimum value of 37.0 mm and a maximum of 64.5 mm, which are similar to ours.

The *length of the condylar path* in the sagittal plane during maximal opening was measured as a curvilinear distance in mm.

In the study of Travers et al. 2000 in adult females the path of the condyles was recorded to be 14 mm for the right and 14.6 mm for the left condyle. In the study of Yoon 2006 the opening of the condyles was found to be between 10.6 and 27.6 mm, in a small group of adults.

In our study, the mean values of the length of the right condylar path are 16.43 mm for the children and 17.51 mm for the adults, whereas for the left condyle the mean values were 17.11 mm and 18.73 mm respectively. The results are highly significant for both groups in both sides.

Gsellmann et al. 1998 using computerized axiography found that patients with anterior disc displacement with reduction showed significantly shorter condylar paths during opening-closing than normal subjects, although this was not observed in all movements and not in both joints. On the other hand, patients with anterior overrotation clicking revealed no significant difference of the length of pathways in opening and protrusive movements, in comparison to the normal subjects. The normal subjects examined showed a mean pathway length of 16.27 ± 4.32 mm on the right side and 15.87 ± 3.86 mm on the left side. In the normal subjects the author found no significant results regarding gender or right versus left side.

In the study of Nishijima et al. 2000 a coincidence of the open and close tracks was observed in the adults but not in children with primary and early-mixed dentitions.

Baqaien 2006 found a mean value of 15.2 ± 3.4 mm for the right condyle and 15.6 ± 3.3 mm for the left condyle in the adults, but no significant differences regarding gender or side. The recordings of the children were 13.7 ± 2.8 mm for the right condyle and 13.0 ± 2.9 mm for the left condyle. Alike the adults the results were insignificant.

In the study of Reicheneder et al. 2008 condylar path inclination ranged between 15.8 and 17.6 mm, with a mean of 16.6 mm on the left side in a group of children aged 6 to 10 years. The mean condylar path length of the adult group was 19.5 mm, ranging from 14.5 to 24.6 mm. The results of the right side were slightly smaller than those on the left side for both groups. The mean condylar path length ranged from 15.6 to 17.3 mm in the juvenile group, with a mean value of 16.4 mm. The mean value of condylar path length of the adult group was 19.0 mm with a minimum of 12.0 mm and a maximum of 24.6 mm. There were no significant differences between the right and left sides of condylar path length in the juvenile and adult groups.

Regarding *retrusion of the condyles* the existing literature is not too abundant. According to the study of Reicheneder et al. 2009 the mean maximum retrusion on the right and left sides was found to be 0.6 mm for the children's group aged 6 to 10 years, while the mean maximum retrusion in the adults was smaller than that of the children's group (0.3 mm for the right and 0.4 mm for the left side). The results were significant between the children and the adults for both sides but there were no significant differences between the right and left sides for any of the groups.

Baqaien 2006 found a mean value of 0.3 mm for both condyles in the children and 0.4 mm for the right and 0.3 mm for the left condyle of the adults. There were no significant differences between the two sides for both groups.

In the present study, retrusion of the condyles was measured indirectly from the ipsilateral laterotrusion. The minimum value in the children is 0.0 mm and the maximum value is 3.2 mm for the right side. The results for the left condyle are similar to those of the right condyle, with a minimum value of 0.0 mm and a maximum of 2.3 mm. The adults showed a minimum value of 0.0 mm in both sides and a maximum value of 1.7 mm on the right side and 1.0 mm on the left side. Our values are higher compared to those of Reicheneder but we agree that the maximum retrusion in adults is smaller than in children.

Referring to *laterotrusions of the incisal point*, Ingervall 1970 found that both adult females and children appear to have a greater ability for laterotrusion to the right than to the left side.

Buschang et al. 2001 examined 27 adult females with normal occlusion. Their results also suggest that laterotrusion to the right is greater (11.45 mm) than laterotrusion to the left (10.98 mm).

Hirsch et al. 2006 examined 1,011 subjects, 486 males and 525 females, with a mean age 13.1 ± 2.0 years. The mean value for laterotrusion to the right was 10.2 ± 2.2 mm and for laterotrusion to the left 10.6 ± 2.3 mm. The difference between laterotrusion to the right and left was significant. The author observed no influence on jaw movement capacity in patients with TMD.

Baqaien 2006 examined 41 adults aged 21 to 44.8 years and 172 children between 6.5 and 13 years of age. In the adults he found the mean value of the laterotrusion to the right to be 10.6 ± 2.1 mm, and for the left side the results were similar to the right side, viz. 10.7 ± 2.1 mm, thus there were no significant differences between the right and the left side. For the children, the mean value was 9.8 ± 1.6 mm for the right side and 9.8 ± 1.49 mm for the left side. There were also no significant differences between the right and left side.

Reicheneder et al. 2009 found that the mean maximum laterotrusion to the right side was 12.2 mm and to the left 11.7 mm in the adult group. The mean maximum laterotrusion of the children was 11.0 mm on the right side and 10.6 mm on the left side. Though, the difference between the right and left side was not significant for both groups.

In the present study, the mean value of the laterotrusion to the right in the children was 9.62 mm and 9.65 mm to the left, whereas in the adults it amounted to 8.92 mm and 9.12 mm respectively. Our results do not agree with previous results as we found larger values for the left side.

The *condylar path inclination angle* was measured by Ingervall 1972 using lateral caphalograms. He found that the condylar path inclination angle measured in relation to the nasion-sella line and the nasal line increases with age.

Widman 1988 found that there is a strong correlation between the anatomic angle of the articular eminence and the condylar path inclination angle recorded axiographically. However, Isberg 1998 showed that the condylar path inclination angle (mean value 61.1°) is significantly smaller than the steepness of the articular eminence (mean value 68.7°).

Ricketts 1950 measured the inclination of the articular eminence and found that steepness increases with age. So he found that at the age of 7.5 years it has a mean value of 46° and at the age of 12.5 years the mean value is 52°. For subjects older than 22 years the mean value is 59°.

Posselt et al. 1961 found that the condylar path inclination as obtained from interocclusal wax records during protrusion is 39.1° on the right side and 40.4° on the left side, with a range of 60°. It was found to be at about 30° to the occlusal plane and 40° to the Frankfurt horizontal plane.

Wessling 2003 investigated 9 normal adult subjects, using the JMA system and the Gamma-Cadiax system in order to estimate the reproducibility of the results and the reliability of the two systems. He used the arbitrary axis. The recordings of the JMA system regarding the condylar path inclination angle are provided below. For the right condyle he obtained a mean value of 46.47 ± 5.66°, whereas for the left condyle the mean value was 44.67 ± 6.33°.

Baqaien 2006 measured the condylar path inclination angle of children aged from 6.5 to 13 years and compared them to an adult group. For the right condyle, 50.2° were recorded at 3 mm of protrusive movement and 46.5° at the first 5 mm of protrusive movement. For the left condyle the mean values were 49.5° and 46.0° respectively. He found no statistically significant differences between the right and the left side. In the adult group a mean value of 63.5° for the right and 62.1° for the left condyle at the first 3 mm of protrusion was recorded. At the 5 mm of protrusion the mean values were 59.1° and 57.7° respectively. There were also no statistically significant differences between the two sides.

The results of Reicheneder at al. 2009 averaged 36.71°and 34.62° for the children and 49.55° and 47.37° for the adults on the right side at the 3 mm and 5 mm of protrusive movement respectively. For the left side the values were similar. More exactly they recorded 36.27° and 34.35° for the children and 49.51° and 47.62° for the adults at the 3 mm and the 5 mm of protrusive movement respectively. There were no significant differences in the condylar path inclination angle at a 3 mm and 5 mm protrusive path between the right and the left sides for both groups.

In the present study the mean value of the condylar path inclination angle in the adult group was 45.86° for the right side and 46.87° for the left side at 3 mm of protrusive movement and 43.29° for the right side and 44.53° for the left side at 5 mm of protrusive movement. The estimated mean values of the children were 36.5° for the right side 36.16° for the left side at 3 mm of protrusive movement and 34.3° for the right side and 33.98° for the left side at 5 mm of protrusive movement. In this study there were also no statistically significant differences between the right and the left side for both children and adults.

The *Bennett angle*, to the best of our knowledge, has not been widely investigated. In a study of Zwinenburg et al. 1996 the Bennett angle was measured in 20 healthy adult subjects with Class I occlusion, using the OKAS 3-D system. In their study they used the palpated lateral pole of the right and left condyle to define their reference axis. They found a mean value of 7.2 ± 3.5° for the right condyle and 9.1 ± 4.5° for the left condyle. They also found that measurement of the Bennett angle depends on the condylar reference points used to define the axis of the movement. This means that the condylar movement paths and angles strongly depend on the choice of reference points. Therefore, the results of different studies had better be compared only when the same reference points are used. Unfortunately, available studies are scarce.

Wessling 2003 in his study, using the JMA system, found a mean value of the Bennett angle amounting to 12.40 ± 5.30° for the right condyle and to 11.70 ± 6.80° for the left condyle.

Baqaien 2006, using the kinematic center, reports that as for the right condyle, the mean value at 3 mm of laterotrusion was 11.2° and 10.0° at the first 5 mm of laterotrusion in the children. For the left condyle the mean values were 10.8° and 10.0° respectively. He found no statistically significant differences between the right and the left side. In the adult group, a mean value of 11.6° for the right and 12.0° for the left condyle at the first 3 mm of laterotrusion was estimated. At 5 mm of protrusion the mean values were 11.0° and 10.2° respectively. There were also no statistically significant differences between the two sides.

The results of the present study are similar to those of Baqaien. As for the children the estimated mean values at the first 3 mm of laterotrusion were 11.61 ± 5.64° for the right condyle and 10.84 ± 5.41° for the left condyle. In both studies the mean value for the right condyle are larger than for the left at 3 mm of laterotrusion. At 5 mm the mean values were 9.18 ± 3.89° and 8.42 ± 4.22° respectively. These results are slightly smaller than those of Baqaien. However, the adults showed clearly larger mean values, in comparison not only to Baqaien but also to Wessling and Zwinenburg. For the right condyle the mean values were 15.64 ± 7.18° at 3 mm of laterotrusion and 13.8 ± 6.15°at 5 mm of laterotrusion. The results of the left condyle were 15.14 ± 6.26° and 12.90 ± 6.06° respectively. Our results were also insignificant for both adults and children regarding the right and left side.

7.2.2. Gender

The association of gender with the different kinematic variables has always been of great interest. There are many studies on maximum mouth-opening capacity and its relation to the gender.

In the present study there was no significant correlation of any of the recorded movements and kinematic variables with the gender of the children. However, some associations were found for the adults; namely laterotrusion to the right and the right Bennett angle at the 3 mm of laterotrusion. Though, results were insignificant after Bonferroni's correction. Our results generally agree with the majority of the available literature.

On the other hand, Hirsch 2006 maintained that gender may influence the distribution of jaw movement capacity in normal subjects. He found that male subjects (10-17 years old) have a greater maximum mouth-opening capacity (1.9 mm more) than females. Moreover, in the study of Westling et al. 1992 the mean value of active maximum mouth-opening was significantly larger for boys than for girls. They examined 96 girls and 97 boys whose mean age was 16.7 and 17.0 years respectively. Ingervall 1970 found no difference in opening capacity or maximal protrusion between boys and girls, whereas laterotrusions were larger in boys.

In agreement to our results are the results of Rothenberg et al. 1991, who examined a group of 189 Caucasian children (mean age 10 years). His findings support that there is no significant correlation between gender and the maximum mouth-opening capacity. The results of Sousa et al. 2008 agree with Rothenberg's and our results. They also found no significant differences for laterotrusions. The results of Baqaien 2006 regarding maximum mouth-opening are in accordance to previous results for both children and adults. For laterotrusions, however, a significant gender difference was found for the children of a mean age of 10 years. Actually, laterotrusion to the right was 1.5 mm larger in boys compared to girls.

Machado et al. 2009 reported no significant differences in maximum mouth-opening and laterotrusion between the genders in Brazilian children aged 6-12 years.

Some studies on maximum mouth-opening capacity report larger values for male than for female adults (Pullinger 1987, Travell 1960). Lewis 2001 reports significant sex differences in adults concerning incisor opening movements, with males having a greater mouth-opening capacity. Although we did not find any significant differences between the genders, our values are somewhat higher in the females.

The study of Reicheneder et al. 2009 revealed no significant differences between the genders for the condylar path inclination angle in the children and the adult group either. In another study of Reicheneder 2009 there were no significant differences according to the gender in both children and adults for incisal laterotrusion and retrusion of the condyles.

Ingervall 1972 found no significant difference for the condylar path inclination angle between genders in a group of 7–year-old children. Also, Baqaien 2006 found no statistically significant differences of the condylar path inclination angle between the genders both for the children and the adults. Moreover, the relationship between the retrusion of the condyles or the Bennett angle and gender was insignificant both for the children and the adults in this study.

In our study condylar path length was insignificantly correlated to gender for both children and adults. Our results are in agreement with those of Gsellmann et al. 1998 who found no significant results regarding gender. Similar results were found by Baqaien 2006.

7.2.3. Facial type

Unfortunately, there are only few studies dealing with kinematic variables as related to the facial type. Ingervall 1971 was the first to investigate the relationship between maximum mouth-opening capacity and facial morphology in young female adults. His findings suggest that the maximum jaw opening varies depending on the length of the mandible, the length of the anterior cranial base and ramus inclination. The SAr-tGo angle was the most significant variable. Rothenberg 1991, in a clinical and cephalometrical study of 189 children ranging in age between 4 to 14 years, found a significant relationship of maximum mouth-opening capacity with mandibular body length and anterior facial height.

Fukui 2002 examined 21 Japanese female adults. His findings agree with those of Ingervall in that facial morphology may influence jaw movements. They are supported by Dijkstra 1999 who found maximum mouth-opening capacity to be associated with mandible length (measured as the distance between the condyle and the incisors of the mandible).

Hirai et al. 2009 investigated the range of mandibular movements in adult patients (25-68 years, with a mean age of 44 years old) with square mandible. These patients appear to have an increasingly restricted maximum mouth-opening capacity in comparison to healthy subjects. Although in this study, mandibular motion was not examined in relation to the facial type, we could compare this sample to a brachyfacial sample with similar characteristics.

In our study, no such findings were observed in the adults. Actually, the dolichofacial type shows the more restricted mean value. This may be due to the fact that our adults group consisted of younger subjects (18 to 34.7 years old). In the present study the brachyfacial children show a more limited range of movement when compared to the dolichofacial and the normofacial group. However, we found no significant correlations between the facial type and the kinematic variables of the mandible and the condyles. It would be reasonable to conduct further investigations with respect to the facial type, as the latter plays a great role in the orthodontic treatment.

7.2.4. Body weight and height

The present study revealed significant correlations between some kinematic variables and the individual's body weight or height. In detail, the right condylar path length was significantly associated with weight in the children. In addition, the condylar path inclination angles of the right condyle at 3 mm and 5 mm of protrusive movement were significant in the adults. Body height appears to influence the condylar path inclination angle of both condyles at 5 mm of protrusion in the children, although these results lost significance after Bonferroni adjustment. In contrast, retrusion of the both condyles in the adults was significantly correlated to height even after Bonferroni's correction.

Our results, thus, do not agree with the results of Ingervall 1970, who found that the maximum mouth-opening capacity in children is positively correlated with body height and weight. Landtwing 1978 supported that there is a great dependency of maximum mouth-opening capacity upon stature and, consequently, body height.

Sousa et al. 2008 found a slightly positive, statistically significant correlation of maximum mouth-opening capacity and laterotrusions with body height. They also found a weakly positive significant correlation between maximum mouth-opening capacity and body weight for a weight range from 17.3 to 46.5 kg. Weight was significantly associated with the laterotrusions, especially in weight ranges below 46.5 kg, where a constant increase of the mean values of the laterotrusion to the right and to the left was observed with increasing weight.

In view of the limited literature available, further studies dealing with the influence of body weight and height on the kinematic variables are suggested.

7.2.4. Overjet and overbite

The role of overjet in temporomandibular dysfunction is controversial. Some authors have related an increased overjet to symptoms and signs of TMD. Pahkala et al. 2004 concluded that excessive overjet > 5mm increases the risk for TMD. The results of Thilander et al. 2002 are in agreement with this suggestion. In addition, Turasi et al. 2007 concluded that patients with increased overjet appear to show significant differences in the range of the slide from centric occlusion to centric intercuspation compared with normal overjet patients, even in non-TMD subjects which may result in orthopaedic instability. The examiner, therefore, should be very careful, always considering possible TMJ problems when treating patients with a large overjet.

Similar findings were obtained by Riolo 1987 who also examined the overbite and concluded that subjects with anterior open bite are more likely to develop TMD. The study of Solberg 1986 supports that malocclusions are associated with TMJ changes. They studied the left TMJ from 96 cadavers (mean age 26.4 years). They performed an intraoral examination before removing the TMJ. In cases with an abnormal overjet an increased deviation of disc shape was evident. In addition, a larger overjet was related to disc displacement. When abnormal overjet was combined with abnormal overbite, a deviation of the condylar form was found. Therefore, the maximum mouth-opening capacity or the laterotrusions may be expected to be limited in these patients. On the other hand, a lacking association between signs and symptoms of TMD and increased overjet has also been suggested (Droukas et al., 1985). Despite the ongoing controversy about the role of overjet and overbite and their relationship with the kinematics of the mandible and the condyles, available studies on this topic are rare, at least to our knowledge.

In a cross-sectional study involving 1.342 subjects aged 6 to 17 years, Riolo 1987 found that maximum mouth-opening was significantly increased when the overjet exceeded 5 mm. Excessive or even negative overjet was positively associated with

TMJ pain. The subjects with an overjet of more than 5 mm showed a mean mouth-opening of 44 mm instead of 42 mm observed in subjects with smaller overjet. Subjects with a normal or greater overbite exhibited a significantly smaller maximum opening capacity compared to subjects with small overbite or open bite.

In our study the only association of the overjet was found with the condylar path inclination angle of the right condyle at the 3 mm of protrusive movement in the children. The correlation was positive, this is to say, the angle increases when the overjet increases. However, the representativeness of this finding is questionable, since no significance was obtained after Bonferroni correction. Moreover, this finding was observed only on the right side while the results of the left side would also be expected to be significant. Furthermore, the association was observed only at the 3 mm of protrusive movement. Possibly, teeth are already in disocclusion at the 5 mm of protrusion and, therefore, the overjet no longer plays a significant role.

Finally, the overbite was insignificantly associated with the retrusion of the left condyle and the laterotrusion to the left in the adults and the left Bennett angle at 3 mm of laterotrusion in the children.

8. Summary and conclusions

This study aimed to investigate the range of mandibular and condylar movements in school children and adults using kinematic variables. Moreover, possible associations of mandibular movements and condylar kinematic variables with specific individual characteristics such as gender, facial type, weight, height, overjet and overbite were studied. In addition, possible differences between the right and the left side of the subjects were examined.

For these purposes, axiographic registrations were carried out on 92 children aged 7.2 to 10.6 years (main group) and 40 adults aged 18 to 34.7 years (control group). For this purpose we used the Jaw Motion Analyzer (JMA-) system which was already tested by other researchers for its accuracy and reliability. Statistical analysis of the recording results was carried out using the SPSS for Windows software. The categorical data (facial type, gender) were evaluated by means of one-way analysis of variance (ANOVA). Significance was tested using the F distribution. The associations of continuous, but not normally distributed variables such as size, weight, overjet and overbite with the dependent variables were described using Spearman's rank correlation rho. Results were considered significant at $p<0.05$. Since multiple testing of interdependent variables was performed, the significance level was adjusted after Bonferroni to $p \le 0,005$.

We used the arbitrary axis-orbital plane as our reference plane which is considered suitable by the manufacturer. The arbitrary axis was defined through the ear tragus superior points of the right and left side. We chose the arbitrary method which has been widely used because it is simple and fast. The bite fork was fastened on the labial surface of the front mandibular teeth. There should be no composite interfering in maximum intercuspation, in order not to affect the function of the mandible. The recorded movements were maximum opening, maximum protrusion, left laterotrusion, right laterotrusion, Posselt frontal and Posselt sagittal. Each movement was repeated twice in order to ensure the accuracy and reproducibility of results. The subjects were asked to sit in an upright and relaxed position, looking straight ahead. Each movement should start and end in maximum intercuspation, and the subjects should perform each movement toothguided and without manipulation.

- The present study supports previous findings that younger school children have not yet reached the maximum mouth-opening capacity of the adults.
- There was no significant correlation between the maximum mouth-opening capacity and gender, facial type, weight, height, overjet or even overbite for both groups.
- A tendency was found in adults that gender may be associated with laterotrusion to the right and the right Bennett angle at 3 mm of laterotrusion (not significant after Bonferroni correction).
- No significant correlation existed between the facial type and the kinematic variables for both groups.
- A tendency was revealed that body weight may be associated with opening of the right condyle in children, and with the right HCN at 3 mm and 5 mm of protrusion in adults (not significant after Bonferroni correction).
- Retrusion of both condyles showed a strong significant correlation with body height in the adults.
- There was a tendendy in the children that HCN of both condyles at 5 mm of protrusion may be associated with body height (not significant after Bonferroni correction).
- A tendency was found for the overjet to be associated with the condylar path inclination angle of the right condyle at 3 mm of protrusive movement in the children (not significant after Bonferroni correction).
- There was a tendendy that the overbite may be associated with retrusion of the left condyle and the laterotrusion to the left in adults and with the left Bennett angle at 3 mm of laterotrusion in children (not significant after Bonferroni correction).
- For condylar path length in both children and adults, significant differences were found between the right and the left side.
- Further investigations are warranted in order to achieve more precise results.

9. Zusammenfassung and Schlussfolgerung

Ziel dieser Studie war es, die kinematischen Variablen des Unterkiefers und der Kiefergelenke von Kindern im Vergleich zu Erwachsenen zu untersuchen. Ein weiteres Ziel galt den korrelativen Zusammenhängen der kinematischen Variablen des Unterkiefers und der Kiefergelenke mit Personenfaktoren wie Geschlecht, Fazialtyp, Gewicht, Größe, Overjet und Overbite. Darüber hinaus wurde überprüft, ob signifikante Unterschiede zwischen der rechten und linken Seite der Probanden bestanden.

Zu diesem Zweck wurde eine axiographische Registrierung an 92 Kindern im Alter von 7,2 bis 10,6 Jahren (Hauptgruppe) und 40 Erwachsenen im Alter von 18 bis 34,7 Jahren (Kontrollgruppe) durchgeführt. Zum Einsatz kam hierbei das Jaw Motion Analyzer (JMA-) System, welches bereits von anderen Autoren hinsichtlich seiner Genauigkeit und Zuverlässigkeit überprüft wurde.

Die statistische Analyse der Ergebnisse erfolgte mit dem Programm SPSS für Windows. Die Verteilung der Untersuchungsvariablen wurde deskriptiv anhand der Parameter Mittelwert, Median, Standardabweichung, Minimum und Maximum dargestellt. Außerdem wurden die kategorialen Daten (Fazialtyp, Geschlecht) mit Hilfe von Einweg-Varianzanalysen (ANOVA) ausgewertet, in die Fazialtyp bzw. Geschlecht als unabhängige Variablen (Faktoren zur Gruppenbildung) und die Untersuchungsparameter als abhängige Variablen eingingen. Die Signifikanzprüfung erfolgte hier über die F-Verteilung. Für stetige, aber nicht normal verteilte Variablen wie Größe und Gewicht, Overjet und Overbite wurde der Zusammenhang mit den abhängigen Variablen mit Hilfe der Rangkorrelation Rho nach Spearman beschrieben. Um das Signifikanzniveau für die Anzahl der abhängigen statistischen Tests zu korrigieren, wurde die Signifikanzschwelle nach Bonferroni auf $p \leq 0,005$ angepasst.

Als Bezugsebene wurde die arbiträre Achse-Orbital-Ebene gewählt, welche in vorherigen Studien geprüft wurde. Die arbiträre Achse wurde durch den Oberrand des Tragus auf der linken und rechten Seite in der Analyse-Software definiert. Wir entschieden uns für die arbiträre Achse, die weit verbreitet ist und einfach und schnell bestimmt werden kann. Die Bissgabel wurde auf den Labialflächen der Unterkieferfrontzähne befestigt. Das Befestigungskomposite sollte die maximale Interkuspidation nicht stören, um die Funktion des Unterkiefers nicht zu beeinflussen. Die durchgeführten Bewegungen waren maximale Öffnung, maximale Protrusion, maximale Laterotrusion nach rechts und links, Posselt frontal und Posselt sagittal. Jede Bewegung wurde zweimal wiederholt, um die Genauigkeit und Reproduzierbarkeit der Ergebnisse sicherzustellen. Die Probanden wurden gebeten, eine aufrechte und entspannte Sitzposition einzunehmen. Jede Bewegung sollte in der maximalen Interkuspidation beginnen und enden, ferner sollten die Probanden jede Bewegung zahngeführt und ohne Manipulation durchführen.

- Die Ergebnisse der vorliegenden Studie unterstützen die Annahme, dass Kinder im frühen Schulalter noch nicht die maximale Mundöffnungskapazität Erwachsener erreicht haben.
- In beiden untersuchten Gruppen bestanden keine signifikante Korrelationen zwischen der maximalen Mundöffnungskapazität und dem Geschlecht, Fazialtyp, Gewicht, Größe, Overjet oder Überbiss.
- Bei den Erwachsenen bestand eine Assoziation zwischen dem Geschlecht und der Laterotrusion nach rechts sowie dem rechten Bennett Winkel nach 3 mm Laterotrusion (nicht signifikant nach Bonferroni-Korrektur).
- Es gab auch keine signifikante Korrelation zwischen dem Fazialtyp und den kinematischen Variablen für beide Gruppen.
- Die Öffnung des rechten Kondylus bei den Kindern sowie der HCN-Winkel nach 3 mm und 5 mm Protrusion bei den Erwachsenen waren mit dem Körpergewicht assoziiert (nicht signifikant nach Bonferroni-Korrektur).

- Die Retrusion beider Kondylen war stark signifikant mit der Körpergröße der Erwachsenen korreliert.

- Der HCN beider Kondylen nach 5 mm Protrusion bei den Kindern war mit der Körpergröße der Kinder assoziiert (nicht signifikant nach Bonferroni-Korrektur).

- Der Overjet zeigte einen Zusammenhang mit dem HCN des rechten Kondylus nach 3 mm Protrusion bei den Kindern (nicht signifikant nach Bonferroni-Korrektur).

- Die Retrusion des linken Kondylus und die Laterotrusion nach links bei den Erwachsenen und der linke Bennett-Winkel nach 3 mm Laterotrusion bei den Kindern waren mit dem Überbiss assoziiert (nicht signifikant nach Bonferroni-Korrektur).

- Die Kondylenbahnlänge bei den Kindern und den Erwachsenen war zwischen der rechten und der linken Seite signifikant unterschiedlich.

- Weitere Untersuchungen sollten durchgeführt werden, um genauere Ergebnisse zu erzielen.

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12. Curriculum Vitae

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